RATTAN CANE HARVESTING IN LAMBUSANGO FOREST, BUTON, INDONESIA: A SUSTAINABLE PRACTICE OR A THREAT TO FOREST CONSERVATION?

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to
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and
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Abstract

Lambusango Forest, Buton, Indonesia, is of conservation importance because of its lowland evergreen tropical rainforest habitat type. The forest is home to endemic Sulawesi mammals including the IUCN redlisted species of Anoa (*Bubalus depressicornis),* Buton Macaque (*Macaca ochreata brunnescens*) and spectral tarsier (*Tarsius tarsier*) and also has abundant rattans (*Calamus* and *Daemonorops*). Rattan cane is an important Non-timber Forest Products (NTFP) and is widely used as a material for furniture and handicraft industries. Rattan cane extraction has long taken place and is entirely manual harvesting of wild rattan canes by local villagers. With growing concerns about deforestation and forest encroachment in the tropics, NTFP extraction has been conceived as a means to balance forest conservation with the needs of local economies. However, the sustainability of rattan cane harvesting in Lambusango forest is unknown.

This research assesses the extent of forest disturbance in Lambusango and its major forest-based livelihood activity: rattan cane harvesting. Assessments are undertaken to investigate the key factors affecting harvesting levels and to determine whether the current practice is sustainable. Sustainability assessments take into account resource sustainability, impacts on forest structure and economic importance to the harvesters.

Forest loss to agricultural uses has mostly taken place in the forest peripheries while the core forest area shows much less change than other zones and there has also been some regeneration. The study area shows levels of woody biomass within the common range of tropical rainforests.

Effects of natural factors on rattan plants and forest vegetation were assessed. Abundance and distribution of rattans are not influenced by natural factors of slope and light regime while soil pH has an effect on abundance of *Calamus ornatus*. It was found that tree species richness and diversity are affected primarily by topographical factors and the woody biomass and size of trees are slightly affected by soil factors. There is no significant evidence of an association between variations in tree and vegetation structure and variations in rattan abundance and presence.

Harvest quantity is affected by natural factors such as terrain and accessibility, although they become less influential where the resource is abundant. Forestry laws enforced through the designated forest zone system (*kawasan hutan*) do not significantly affect levels of harvesting. Demographic and socioeconomic factors only marginally influence the economic importance of cane harvesting. There is some indication that more profitable, more intensive and less rigorous livelihood activities are favoured by some harvesters, making them less rattan dependent. Harvesting was found to impact understorey vegetation density and tree regeneration. A

combination of natural competition and anthropogenic factors adversely affect tree-stem density.

Maintaining a low level of harvesting can ensure resource sustainability. Two conceptual scenarios for the future of cane harvesting in Lambusango forest are discussed: sustainable harvesting and non-forest-based livelihoods. With a long-standing and important forest extraction activity such as rattan cane harvesting, sustainable harvesting is one pathway that can contribute to local livelihoods. Because evidence showed that only minimal impacts have occurred on forest structure and a sustainable harvest level can be maintained, efforts towards sustainable practice should be supported. Sustainable rattan cane extraction may work in combination with the ongoing efforts for sustainable management of Lambusango forest, such as those initiated by Lambusango Forest Conservation Programme (LFCP) and other potential schemes such as development of rattan agroforestry, certified NTFP and incentive-based mechanisms for forest protection.

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Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. The work was done in collaboration with Operation Wallacea Trust – Lambusango Forest Conservation Programme

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Signature:

Date: October 2009

Chapter 1. Forest conservation efforts and local livelihoods: the case of rattan cane harvesting in Lambusango Forest

1.1 Introduction

1.1.1 Tropical forest richness and human impacts

Tropical rainforest has long been understood to provide important environmental services ranging from watershed function protection, carbon storage to biodiversity richness. Of the world's terrestrial habitats, tropical rainforests have the highest plant biodiversity per unit area (Richards, 1981; Whitmore, 1990; Whitten *et al*, 2002).

Despite the rich biodiversity, forests in the tropics have largely been affected by human activities to various levels and extents (Mbile *et al.*, 2005; Ruiz Perez *et al.* 2004; Quang and Anh, 2006; Bawa *et al.*, 2007; Ndalangasi *et al.*, 2007). Human impacts are an inseparable part of the historical context to forest dynamics so that what are known as natural forests at present are often the products of historical human disturbance and management, such as in middle America with Mayan and Aztec civilisation and European settlements, and in Asia where ancient agriculture occurred in the past (Whitmore, 1990). Dependence on tropical forests is still prevalent today, involving a variety of forest products, different levels of importance to livelihoods, and various scales of extraction or utilisation. Forest-dependent people in the tropics can be categorised into different types which range from indigeneous shifting cultivators, farmers who extract forest products for subsistence up to large forestry entrepreneurs (Byron and Arnold, 1999; Sunderlin *et al*., 2005). Sunderlin *et al*. (2005) further stated that forest can have various roles for people including land provision for agriculture, timber and non-timber extractions, environmental service provision and other indirect benefits.

Depending on the types and especially the scale of the activities, impacts of human activities on the forest can range from complete loss of forest area, or deforestation, down to light disturbance on different forest characteristics. In terms of area loss from 1990 to 2005, Food and Agriculture Organisation (FAO) reported that approximately 650,000 km^2 of tropical forest in 56 countries was deforested (FAO, 2009a). The impacts of small-scale forest product extraction that does not cause area loss are much more difficult to assess due to the subtlety of the problems compared to deforestation, especially when only small scale local activities are involved such as Non Timber Forest Product (NTFP) extraction.

1.1.2 Non timber forest products (NTFPs)

1.1.2.1 Definition of NTFP

The meaning of the term 'NTFP' has long been discussed and defined by scholars. Belcher (2003) noted that the term NTFP originated from de Beer and McDermott in 1989, who defined NTFP as '*biological materials other than timber which are extracted from forests for human use*'. These products range from all plants, fungi and animals for which the forest ecosystem provides habitat (de Beer and McDermott, 1989, in Belcher, 2003). Other terms that have been introduced by various sources for forest products other than timber are 'non-wood resources' (Peters *et al.*, 1989), 'minor forest products' (e.g. in Whitmore, 1990), 'other forest products', 'forest biological resources' and many others (Belcher, 2003). A widely used term that was formally defined by FAO is 'Non Wood Forest Products' (NWFP), which is defined as '*goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests*' (FAO, 1999). The greatest difference between this latter term and NTFP lies in the exclusion of all 'woody' products other than timber, such as fuelwood, woodchips and charcoal, which are included in the NTFP definition. 'NTFP' was originally defined on the basis of separating small scale forest product extractions by local people from the industrial scale of timber extraction which is normally the interests of external parties from outside the forest areas (de Beer and McDermott, 1989, in Belcher, 2003), and therefore minor woody materials are considered in this category.

Due to the economic value of NTFPs which benefit the livelihood of forest-dependent people, many of the wild products are then cultivated or domesticated. This has led to the broadening of the ecosystem types from which NTFPs are extracted, from only natural ecosystems to both natural and anthropogenic ecosystems. As a result, the definition of NTFP also includes those harvested from man-made land use systems, such as agroforestry or mixed plantations (e.g. in Ros-Tonen and Wiersum, 2005). However, having considered the various definitions and contexts of NTFP, for the remaining part of this thesis, NTFP is used to refer to materials harvested wild from the forest or at least non-cultivated forest products.

1.1.2.2 NTFP to balance conservation and livelihood

In developing countries, extraction of NTFPs from the forest is long-established and can be an important livelihood strategy for local people living in and around forest. The extraction is commonly conducted by the poorer members of society, who are not able to apply intensive farming and who have few alternative livelihood strategies. As NTFPs are usually free goods that do not require capital or skills for their utilisation, they can play a key role as an immediate cash source for forest-dependent people even where they are not fully commercialised. To this end, NTFPs assume one or two roles in the livelihoods of forest dependent people: for subsistence uses and as an income safety net for the poorest in society (Ros-Tonen and Wiersum, 2005; Ambrose-Oji, 2003; Ndalangasi *et al*., 2007).

With growing concern about deforestation and forest encroachment, and the maintenance of forest ecosystem services, NTFP extraction has been conceived as a means to balance forest conservation with the needs of local economies. Past and ongoing studies and reviews have evolved the debates on the combined conservation and economic benefits of NTFP extraction, considering how NTFP extraction can maintain the structure and cover of the forest and provide incentives for local people to preserve the forest (Peters *et al*., 1989; Arnold and Ruiz Perez, 2001). However, the combined ideas of balancing conservation and livelihood importance should be seen from the different dimensions that each represents, i.e. by understanding where they coincide, where they conflict and by identifying the realistic balance (Arnold and Ruiz Perez, 2001). Sunderlin *et al*. (2005) identified that the outcomes of forest conservation and poverty alleviation efforts, including by means of NTFP harvesting, can result in four possible combinations of the two: win-win, win-lose, lose-win and lose-lose, and suggested that research and development should pay attention to both site level and external factors.

This latter discussion is of greater concern when an NTFP is commercialised and its management is intensified including through cultivation and domestication. Commercialisation of an NTFP as a means to improve the livelihoods of harvesters implies more intensive extraction in the forest, which can substantially reduce resources in the forest, or it may move towards intensified management and cultivation (Belcher *et al*., 2005). The irony of this premise is that while it aims to elevate the income of the poor, it likely will miss the poorer in society because they normally have a weaker position regarding market access, which is an important part in commercialisation (Arnold and Ruiz Perez, 2001; Belcher *et al.*, 2005; Ambrose-Oji, 2003). Belcher and Schreckenberg (2007) discussed a number of cautions associated with promoting NTFP as a ‘silver bullet’ for combining livelihood and conservation. However, it was also noted that with careful interventions, NTFP commercialisation can be a low-risk practice (Belcher and Schreckenberg, 2007).

Other approaches to balancing biodiversity conservation and livelihood improvements have emerged since the Convention on Biological Diversity (CBD) in 1992. Integrated conservation and development initiatives have been devised to ensure that protection of biodiversity also addresses poverty issues. Various land use systems are promoted to achieve both agricultural production and biodiversity conservation. ‘Forest gardens’, ‘ecoagriculture’ and ‘agroforestry’ are among those discussed as part of integrated landscape approaches (Scherr and McNeely, 2008; Wiersum, 2004; McNeely and Schroth, 2006) as well as part of sustainable forest management (SFM) (van Noordwijk *et al*., 2003). Cultivation of various NTFPs can contribute to these mixed systems and livelihood improvements are sought through actions ranging from product domestication to market access (Leakey *et al*., 2005; Ros-Tonen and Wiersum, 2005).

1.1.3 Issues of sustainable NTFP extraction

Ecologically sustainable NTFP harvesting can be seen as comparatively beneficial due to its lower destruction compared to timber extraction or other extensive utilization of the forest (Arnold and Ruiz Perez, 2001). In addition, by securing continuing access to forest products contributing to livelihoods, NTFP extraction provides incentives to retain the forest and prevent it from being cleared and encroached on by other uses (Arnold and Ruiz Perez, 2001)

For the resources in question, harvesting may be destructive and remove the entire or major parts of the plants or in other cases it can be considered a non-destructive method; the former will inevitably lead to rapid resource depletion, while the latter may leave scope for sustainable resource use (Arnold and Ruiz Perez, 2001). Therefore sustainable NTFP harvesting should consider the demographic characteristics of the plants being harvested (Ticktin, 2004). Ecological sustainability considerations also involve the effects of harvesting on the ecosystems the resources share with other life forms. Various indicators can be applied to show the impacts of NTFP harvesting (Hall and Bawa, 1993; Shahabudin and Prasad, 2004; Ticktin, 2004; Ruiz Perez and Byron, 1999). The indirect consequences of extraction, for example in transporting the products, might also contribute to the adverse effects on ecosystems (see e.g. in Siebert, 2002 and 2004).

Livelihoods and economies of the harvesters or local people affected by the activity play a similarly important role in assessing the sustainability of NTFP extraction (Clayton *et al.*, 2002; Ross-Tonen *et al*, 1998). Neumann and Hirsch (2000) discussed various methods for assessing the ecological implications of commercial NTFP harvesting, including socioeconomic factors, but the authors also pointed out that using real world cases for the assessments would always entail uncertainties because the method fails to filter out the other causal factors which are untested.

1.1.4 Rattan cane: one of the most commercial NTFPs

One important NTFP extracted from forests in the tropics is rattan cane. Rattan cane is one of the most commercial NTFPs and is a common material for furniture and handicraft industries. Rattans are spiny climbing palms from the family of Palmae or Arecaceae (Sunderland and Dransfield, 2002), mostly from the subfamily Calamoidea (Dransfield and Manokaran, 1994). Rattan is mainly distributed in tropical Asia, especially Southeast Asia, tropical Africa and Northern Australia (Rachman and Jasni, 2006). The rattan genus with the most species in Asia, including Indonesia, is *Calamus*, having approximately 370 species (Dransfield and Manokaran, 1994). Indonesia has approximately 300 species of rattan, 50 of which are commercial (Rachman and Jasni, 2006). The genera of rattans in Indonesia are *Calamus* (approx. 190 species), *Daemonorops* (approx. 78 species), *Korthalsia* (approx. 20 species) and *Ceratolobus* (approx. 10 species) (Rachman and Jasni, 2006).

The word rattan is derived from the Malay word *rotan* which is a local term for climbing palms (Sunderland and Dransfield, 2002). It is said to originate from the word *rautan* which means "obtained from being peeled" (*raut (v)* = to peel). *Rautan* goods are any thin and long objects produced from the process of peeling, and are normally used for matting into mats, chairs, tables, baskets, etc. (Rachman and Jasni, 2006). The important product from rattan plants is the cane, which is the stem stripped of its leaf sheaths and is strong, solid, uniform yet highly flexible (Dransfield and Manokaran, 1994; Sunderland and Dransfield, 2002). The canes are widely used as materials for furniture industries and for basketry or handicrafts, and can be used either in their whole round form or split/peeled (Figure A8.4(b)). Rattan canes are recognised as important commercial non timber forest products from tropical countries such as Indonesia (Dransfield and Manokaran, 1994; Belcher, 2001/2; Rachman and Jasni, 2006). Rattan canes vary in diameter, but can be classified into 'large' and 'small'. Large diameter canes are greater than 18mm, and the most common species in the rattan trade is *Calamus manan* (*Rotan Manau*), while the most common small diameter species is *Calamus caesius* (*Rotan Sega*) (Rachman and Jasni, 2006).

Rattan cane producers are mostly third world countries, and for South East Asia, including Indonesia, rattan canes are the most important commercial NTFP. Indonesia is one of the biggest producers of raw rattan cane (Clayton *et al.*, 2002; Dransfield and Manokaran, 1994; Rachman and Jasni, 2006), and the industry has been growing for decades since the early 20th century when rattan canes were exported from Kalimantan and Sulawesi (Dransfield and Manokaran, 1994). In the past, rattans were mostly exported as raw canes and were the second greatest forest product commodity after timber (Rachman and Jasni, 2006). In 1977 cane export was estimated to be worth US$ 15 million (Sunderland and Dransfield, 2002). Throughout the following decades until 2005 several policy changes took place regarding rattan exports (Rachman and Jasni, 2006; Vantomme, 2003; Erwinsyah, 1999). However, despite the changes of the laws and consequently cane price, rattan collection continued to be widely practiced by local villagers in many parts of Indonesia, because for most it had become one of their major income sources.

1.1.5 Forestry, NTFP and rattan in Buton

Buton, the island where this study is conducted, is located southeast of the island of Sulawesi, Indonesia. Forest in Buton is considered an important tropical biodiversity hotspot because it houses several endemic fauna species including anoa (*Bubalus depressicornis*), tarsier (*Tarsius spectrum*) and macaque (*Macaca ochreata brunnescens*) (Seymour, 2006). However, as is the case with many forests in the tropics, degradation and area loss have been occurring in Buton. Based on satellite imagery analyses of 1991-2002, Carlisle (in progress) calculated that at least 15 % of forest has been lost on Buton.

NTFP extraction also occurs in Buton forest, most importantly rattan cane. The extraction has long taken place and is entirely as wild rattan canes harvested manually by local villagers living surrounding the forest. For Buton Island, rattan export has taken place since the colonial era of the 19th century (Velthoen, 2006; Rabani, 2004), and there is evidence of rattan’s importance in the island’s economy during the 1920s together with dammar and capok (Rabani, 2004). The rattan trade in Buton, as in other islands of Indonesia, continued to grow up to the boom period of the 1970s and 1980s when the export of raw and semi processed rattan canes was still allowed and Indonesia became the world’s greatest rattan exporter (Dransfield and Manokaran, 1994; Rachman and Jasni, 2006).

1.1.6 Lambusango forest where conservation meets forest utilisation by locals

One part of Buton, where tropical biodiversity richness coincides with forest extraction by local people, is Lambusango forest located in the central part of the island. Around Lambusango forest, people living in the villages are engaged in activities directly or indirectly linked to the forest, namely timber extraction, NTFP extraction, forest area encroachment, and hunting. A preliminary report by Milsom (2004) noted that these activities are potential threats to the forest and its wildlife.

Several major issues of concern related to the preservation of Lambusango Forest have been reported (Purwanto, 2006). Forest disturbance threats in Lambusango are, among others, establishment of new transmigration settlements (Figure A8.5), the planned forest conversion into oil palm plantation, and the reestablishment of asphalt mining. To various extents, the forest is also affected, but not lost, by selective timber extraction and rattan cane harvesting (Carlisle, in progress).The level of disturbance caused by these activities has not yet been assessed.

Encroachments on the forest to establish agricultural fields have been taking place for decades in the form of shifting cultivation in which farmers plant annual crops for their subsistence. At present permanent farming practices are important sources of income for the villages around Lambusango (Figure A8.6). A preliminary report on baseline socioeconomic conditions found that farming activities including livestock contribute between 13%-45% of the mean income (Malleson, 2005). The farming practices range from irrigated rice, upland rice to perennial/cash crops like cocoa, cashew nuts, coconuts, and coffee.

Interactions between local people and Lambusango forest have been taking place at least since the mid-1900s (Rahim, personal communication), characterised by forest dwelling and shifting cultivation in the forest (Purwanto, 2008b). In the 1970s and 1980s a new forestry policy led to eviction of forest dwellers and resettlement in villages outside the forest (Purwanto, 2008b). The policy reflected government’s rejection of local community access to the forest, the forest-dwelling lifestyle and resource management practices. Shifting cultivation was considered economically unproductive and ecologically destructive. The suggested alternative livelihood activities included sedentary farming and urban-based livelihoods (Purwanto, 2008b).

In response to the need for reinforcing forest conservation amidst the utilisation of forest by local people, a four-year project called Lambusango Forest Conservation Programme (LFCP) was established and run by Operation Wallacea Trust, UK, funded by the Global Environment Facility (GEF)/World Bank. The programme aimed to procure necessary technical services and related resources to facilitate the development of cohesive and comprehensive conservation activities involving all forest stakeholders, which would enable increased forest protection and reduce the level of threat to Lambusango Forest (Purwanto, 2008a).

A number of components were developed within this programme consisting of 'forest management and village development', 'enforcement', 'environmental education and awareness' and 'capacity development for biodiversity assessments and monitoring'. In brief, the specific objectives of LFCP activities are (Purwanto, 2008b):

- to develop a Community Forestry Management Forum as a mature organisation able to conduct independent conservation movements
- to develop a sustainable livelihood model for villages surrounding the forest through village conservation contract facilitation schemes
- to provide enabling conditions for better forest management and sustainable rattan extraction
- to strengthen forest crimes law enforcement
- to promote the global significance of Lambusango Forest through development of specific teaching materials
- to raise awareness among Lambusango forest constituents and stakeholders at local and national levels
- to provide grants for building capacity of students and local conservation staff to conduct biodiversity assessments and monitoring

1.1.7 Rationale and values of the thesis

This PhD study contributes to the fourth component of LFCP (capacity development for biodiversity assessments and monitoring), while at the same time also providing a specific case study on NTFP issues as part of sustainable forest management strategies.

The various forest uses cause disturbance to Lambusango forest, with preliminary evidence of area loss mentioned earlier in this section. The extent of the disturbance and how much it relates to the activities of locals is unknown. However, it is clear that close relationships between the forest and people around Lambusango have long been established, and it is important that sustainability of the forest works side-by-side with efforts towards creating sustainable livelihoods. Thus this research assesses the extent of forest disturbance in Lambusango and further studies its relationship with the major forest-based livelihood activity: rattan cane harvesting. The key factors affecting harvesting levels are assessed to determine whether the current practice is sustainable. Sustainability assessments look at rattan cane harvesting practices from three strands of discussion namely ecological impacts, resource sustainability and economic importance. The approaches have been widely applied for other natural resource products, including NTFPs (see e.g. in Clayton *et al*, 2002; Ros-Tonen *et al*, 1998). However, such an approach has particular complexities and uniqueness, especially in the context of Buton and Southeast Sulawesi region, in an area strongly inclined to wildlife protection under the pressure of global biodiversity initiatives[1] while also housing profitable forest products and with long-standing forest-dwelling activities. The outcome of this study will contribute towards sustainable forest management for Lambusango forest by providing arguments and discussions based on sound and well-researched evidence.

[1] Anoa dwarf buffalo (*Bubalus depressicornis*) which is endemic to Sulawesi is listed as an IUCN red list species (IUCN, 2009)

1.2 Problem setting

1.2.1 Problem definition

A flow diagram of the problems defined and addressed in this research is presented in Figure 1.1.

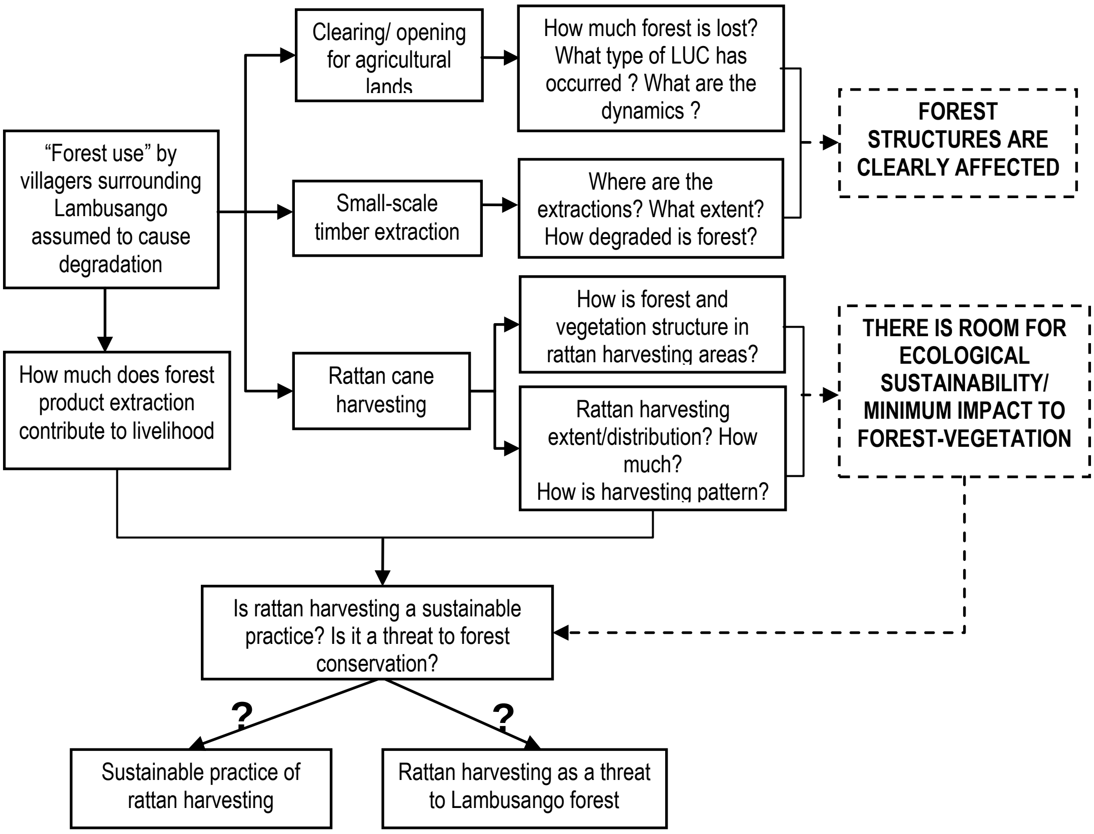


Figure 1.1. Flow diagram of the problem setting in the study area

1.2.2 Overall aim and research questions

The overall aims of the PhD research are to assess sustainability of wild rattan cane harvesting in Lambusango forest by taking into account its resource sustainability, impacts on forest structure and economic role to the harvesters. Specific objectives of the various topics presented in this thesis can be summarised as below:

1. To quantify forest area loss and degradation in Lambusango and assess the dynamics of land use changes surrounding the forest using remote sensing approaches and to investigate the relationships between satellite images' attributes with above ground biomass as the initial indicator of forest structure
2. To assess the distribution and abundance of rattan species and their associations with environmental factors and other understorey vegatation.
3. To quantify rattan cane harvesting levels and assess whether harvesting levels are affected by accessibility factors and conservation designations.

4. To assess the structure and diversity of tree and other forest vegetation and the impacts of rattan cane harvesting
5. To assess the relationship between rattan harvesters' demographic and socioeconomic characteristics with effort, income, dependence and profitability of rattan cane harvesting
6. To observe the main factors affecting rattan cane harvesting preferences and to investigate the indications of cane harvesting sustainability as a basis to discuss the activity as a sustainable secondary livelihood strategy.

1.3 Conceptual framework

To achieve the final objective of the study, there are several compartments of topics each with relevant data and methodologies, which are shown in Figure 1.2. Primary and secondary data were collected for the topics; the first included forest and village data and the latter incorporated spatial data and statistical figures from various sources. For primary data collection, three approaches were applied: forest survey, questionnaire survey and focus group discussion (FGD). A number of data analysis methods were later incorporated which can be broadly categorised into remote sensing imagery analyses, spatial analyses/Geographic Information Systems (GIS) and statistical analyses. A number of outputs are produced, all of which lead to the final objective i.e the discussion on rattan cane harvesting as a viable alternative income source for villagers in Lambusango area.

1.4 Description of study area

1.4.1 Buton Island and Lambusango area

Sulawesi and its smaller neighboring islands, including Buton, are within the Wallacea region, straddling the Wallace Line, which runs between Kalimantan and Sulawesi and, to the south, between Bali and Lombok islands (Figure 1.3). This biogeographical line separates the faunal diversity of the Australia and Eurasia continents. A high proportion of Sulawesi's faunal species are endemic. Endemic fauna found on Buton include Anoa lowland dwarf buffalo (*Bubalus depressicornis*), which is an IUCN red-list species (Seymour, 2006; Semiadi, G. *et al.*, 2008 in IUCN, 2009).

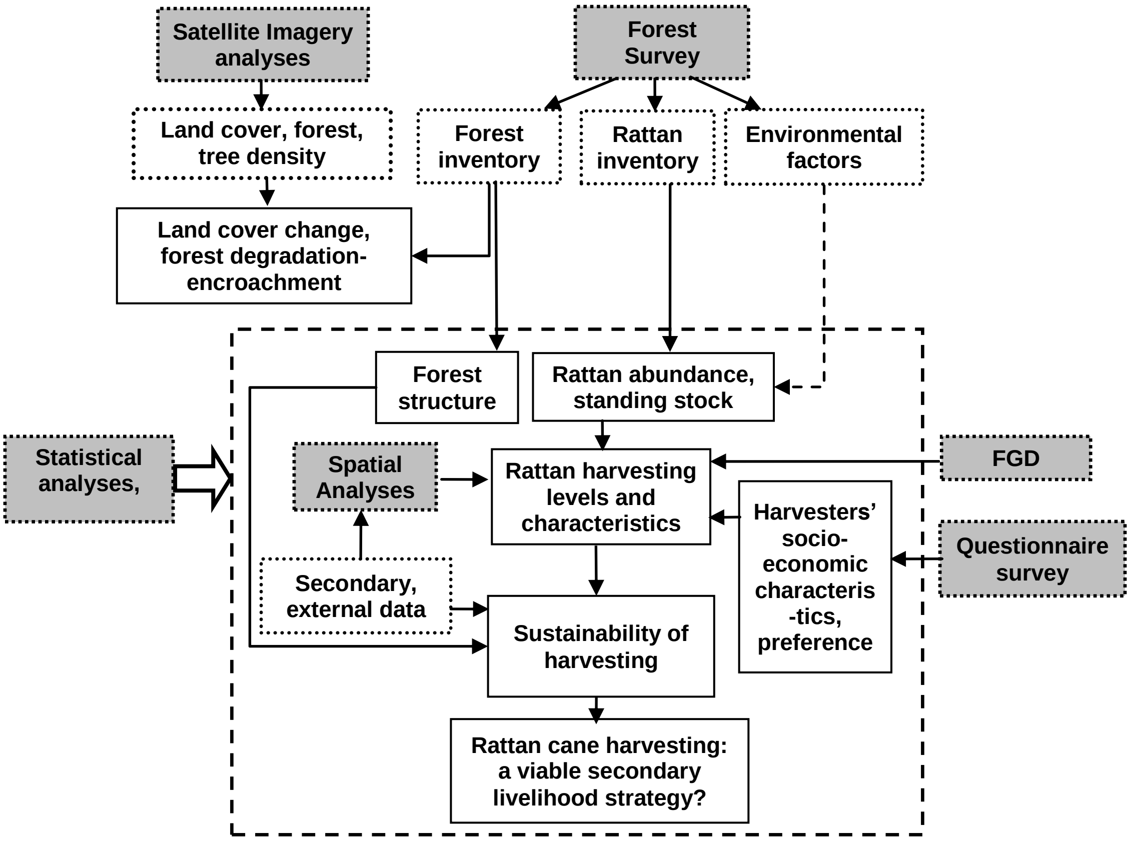


Figure 1.2. Overall framework of methods and data collection of the study

The geologic formation of Buton is upper tertiary marine sediments and to a lesser extent quaternary sediments. Asphalt is impregnated in limestone areas in the southern part of the island (Whitten *et al*., 2002). The annual rainfall is 1500-2000 mm with three to four dry months a year (Whitten *et al*., 2002).

The entire Buton Island is under one administrative authority: *Kabupaten Buton* (Buton district). One district is divided into several subdistricts locally called *Kecamatan*, each subdistrict consists of several villages (*Desa*) and each village usually consists of a few hamlets (*Dusun*). Buton district comprises subdistricts in Buton Island and also in the isles around Buton Island. There were 10 subdistricts within Buton Island in 2005 (*BPS*, 2006).

The study area is located in the central part of Buton Island, geographically between 5°S, 122.68°E and 5.5°S, 123.22°E. Elevation ranges from sea level to 750 m above sea level (asl). The name Lambusango Forest originally came from the official name of the wildlife reserve in this area: "*Suaka margasatwa Lambusango* (Lambusango wildlife reserve)" but in this study is applied to approximately 93,000 ha of lowland evergreen forests in central Buton (Figure A8.1), which includes the wildlife reserve and other designated forest zones around it.

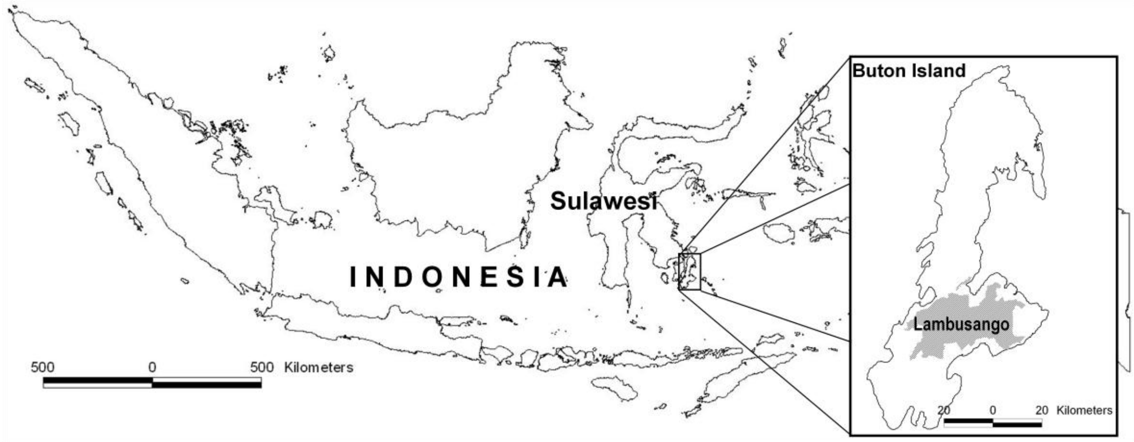


Figure 1.3. Locations of Buton Island and Lambusango Forest

The Indonesian national forestry authority (*PHKA*) designates different types of forest zone (*PHKA*, 2008). Lambusango forest is made up of ± 27,000 ha of Lambusango Wildlife Reserve and ± 68,000 ha of Protection Forest (*Hutan Lindung*), Production Forest (*Hutan Produksi*) and Limited Production Forest (*Hutan Produksi Terbatas*). 'Wildlife Reserve' is one form of conservation designation, defined by the national forestry authority as a nature reserve having unique or diverse wildlife and requiring protection and maintenance to ensure the persistence of its habitat (*PHKA*, 2008). Based on the regulations associated with this designation (*Undang Undang no 5/1990* on conservation of biological resources and their ecosystems), no extraction of flora or fauna is allowed from wildlife reserves and other reserves (President of the Republic of Indonesia, 1990). Protection Forest is defined as an area protected for its hydrological functions, while Production Forest is where extractions under various regulations are allowed to take place. Approximately 60,000 ha of land designated as Non-forest Zone surrounds the forest. In total, the study area covers approximately 160,000 ha, or 1600 km^2. For simplicity, throughout this thesis, Wildlife Reserve is referred to as Conservation Forest and both Production Forest and Limited Production Forest are called Production Forest (Figure 1.4).

1.4.2 Study area and overall sampling design

Related to the specific objectives of this study, sampling strategies were applied in such a way that samples would be obtained from the forest for data on forest structure and rattans, and from villages for data related to the socioeconomics and livelihoods of harvesters. Each of the sample sites are explained in the following sections.

1.4.2.1 Forest sample sites

Six forest sites had been established prior to this study with transects for various biological monitoring of Lambusango forest (Seymour, 2006). The six sites take into account geographic distribution and variations of topography and designated forest zones. The sites' names are Bala (or Balanophora), Lapago, Anoa, Wahalaka, Wabalamba and Lasolo, and their locations are shown in Figure 1.4. In relation to the three designated forest zones, one site is in the core of the

Conservation Forest (Anoa), three are located at/towards the edge of the Conservation Forest (Lapago, Wahalaka and Wabalamba) and two are in the Production Forest (Lasolo and Bala). Sample plots for tree, vegetation and rattan inventory were established within these six study sites, with the detailed sampling design described in the respective chapters throughout this thesis.

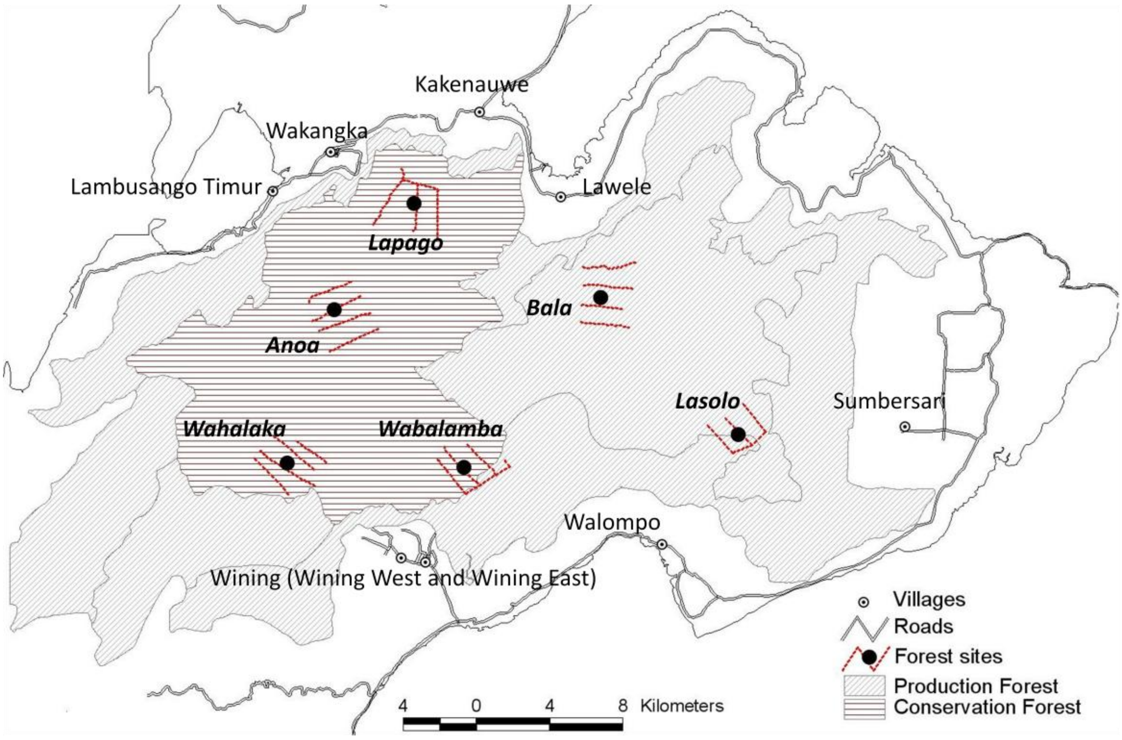


Figure 1.4. Lambusango Forest, forest sites and villages in the study area

1.4.2.2 Sample villages

Determination of villages to be sampled was based on where harvesters who harvest in the six forest sites come from. Consequently, there are seven villages included in the study area, namely: Lambusango Timur, Wakangka, Kakenauwe, Lawele, Sumbersari, Walompo and Wining (Figure 1.4). Later it was discovered that harvesters from Wining village go in two directions, hence to two forest sites, for rattan cane harvesting. Wining was therefore divided into two village sites: Wining West and Wining East. Although a study site can either be an entire village or particular hamlets within a village, for simplicity, the term ‘village’ is used to refer to ‘village study sites’. For further easy usage, the term “Lambusango area” is used when referring to the entire forest and the villages included in this study.

Prior to 2003 the villages in the study area were under the administration of three subdistricts. In 2003, there was administrative reorganisation in Buton and the villages in the study area were located within four subdistricts (*Kecamatan*) as follows: Lambusango Timur and Wakangka located in Kapontori subdistrict, Kakenauwe and Lawele in Lasalimu subdistrict, Sumbersari and Walompo in Lasalimu Selatan subdistrict, and Wining in Pasarwajo subdistrict. In 2007 there was another administrative reorganisation in Buton district and due to the breakdown of

Lasalimu Selatan subdistrict, Sumbersari and Walompo villages are now within Siontapina subdistrict. However, relevant to the research period of this PhD study, 2003-2006 administration divisions were applied in this study. Table 1.1 summarises the administrative structure of the villages in the study area.

Table 1.1. Villages, administrative status and respective forest sites

No	Village site	Administrative status	Village name	Subdistrict	Respective forest site
1.	Lambusango Timur (LBT)	Village	Lambusango Timur	Kapontori	Anoa
2.	Wakangka (WKK)	Village	Wakangka	Kapontori	Anoa
3.	Kakenauwe (KKW)	Village	Kakenauwe	Lasalimu	Lapago
4.	Lawele (LWL)	Village	Lawele	Lasalimu	Bala
5.	Sumbersari (SSR)	Village	Sumbersari	Lasalimu Selatan	Lasolo
6.	Walompo (WLP)	Village	Walompo	Lasalimu Selatan	Lasolo
7.	Wining East (WNE)	Hamlet	Wining	Pasar Wajo	Wabalamba
8.	Wining West (WNW)	Hamlets	Wining	Pasar Wajo	Wahalaka

Lambusango Timur, located in the northwestern part of the study area, is a newly established village, less than one year old, which used to be a hamlet under the jurisdiction of its now neighbouring village. Due to its location, by the bay, people have been embracing coastal-based livelihood activities mainly mother-of-pearl and seaweed cultivation. **Wakangka** village is a major village in Kapontori subdistrict. It consists of four hamlets, with three of them housing rattan harvesters, while one is a Balinese migrant village where the villagers are only engaged in farming, mainly paddy rice. **Kakenauwe** village is located at the crossroads of the two major roads from the northern and from the eastern parts of the island. For approximately the past 15 years, Kakenauwe has been the basecamp for the Operation Wallacea expedition, a forest-based eco-scientific-tourism project conducted annually. This has become somewhat permanent additional income to local villagers for 2-3 months in a year by providing accommodation and labour to the visitors. **Lawele** village is located on the Sinapuli river flood plain and has vast areas of paddy rice fields, with one hamlet located on the coast. **Sumbersari** village was originally a settlement for transmigration settlers from Java joining the government's transmigration programme. The villagers still strongly hold their Javanese identity, which can be clearly recognised by the language they use. **Walompo** consists of three hamlets, all of which are involved in forest extraction activities including rattan cane harvesting. **Wining** village is, like Sumbersari, located relatively in the hinterland, being away from the major roads encircling the southern part of the island. Despite the less-accessible location, Wining has more varied livelihood options due to the presence of asphalt mining and an electricity power plant in the vicinity. The asphalt mining company has only recently been reoperating and thus recruiting labour, creating work opportunities for the villagers. Wining consists of four hamlets, two of them, Kabongka and Rampea, forming the Wining west site for this study and one of them, Montowu Jaya, is the Wining east site.

1.5 Organisation of the thesis

This thesis is organised into eight chapters, each of which is a self-contained chapter with its own objectives, research questions, methods, results and discussions. Exceptions are Chapter One, which serves as an introductory chapter for the entire thesis, and Chapter Eight, which is the conclusion of and reflection on the entire PhD research.

As an introductory chapter, **Chapter One** presents the background to the importance of conducting this PhD researchand describes current forestry and livelihood settings in the study area. Description of the study area followed by sampling extent and definitions are also introduced in this chapter. In **Chapter Two**, a landscape approach to land cover and forest cover dynamics in the vicinity of Lambusango forest is presented. Results of time series satellite imagery analyses and relationships between image attributes and aboveground biomass of the trees in the forest are discussed.

Upon understanding the broad landscape dynamics, the thesis zooms in to the core subject of the study: rattans. In **Chapter Three**, investigation of rattan species abundance in the forest sites for both plants and canes is presented. In order to understand the distribution of species abundance, influences of topographical and environmental factors are assessed. The relationship between rattan plants and other understorey vegetation is also assessed in this chapter. Still focusing on rattans, **Chapter Four** starts to connect rattans in the forest with human activity, i.e. rattan cane harvesting. Discussion of harvesting quantities (or later expressed as “harvest levels”) and effects of accessibility factors in the forest are presented here. Regulatory factors such as the existence of conservation forest boundaries are also incorporated.

With regards to the ‘impacts’ of cane harvesting, forest structure and diversity are assessed and dealt with in **Chapter Five**. The chapter starts with observation of the effects of topographical and environmental factors on forest structure and diversity and continues to assess the impacts of rattan cane harvesting.

Rattan cane harvesting as a livelihood activity triggers questions of what the main factors are that affect the intensity of harvesting. In **Chapter Six**, discussions are presented on the investigations into which socioeconomic characteristics affect harvesters in their harvesting levels. **Chapter Seven** discusses the sustainability of rattan cane harvesting in Lambusango forest and whether it can be sustained as a secondary livelihood practice. The discussion starts with harvesters’ preferences for continuing this livelihood activity and the underlying reasons. Sustainability of harvesting is then discussed, incorporating the three components of ecological sustainability, impacts on habitats and livelihood dependence and profitability. The chapter ends with two possible directions to rattan cane harvesting for villagers in Lambusango area: sustainable harvesting or a non-forest-based livelihood option.

Chapter eight emphasises the relevance of this study in the evolving discussions of NTFP harvesting as part of sustainable forest management. In addition to that, external schemes in line with the current global green movement are considered as possible opportunities that may be introduced to Lambusango forest in the context of sustainable management.

Chapter 2. Land cover change and forest degradation: a Remote Sensing application

2.1 Introduction

2.1.1 Assessment of land cover change and forest degradation

Various objectives in natural resource management and forest management in particular require understanding of the dynamics of land use and land cover. The dynamics of land cover can be classified into two, land cover conversion and land cover modification (Lambin, 1999) which refer to the degree of change as well as time involved. For forest cover, the first commonly refers to forest conversion or encroachments to other uses, while the latter means some extent of degradation that results in the reduction of the tree cover and/or forest quality in general, but does not convert the forest into different land or vegetation cover.

The term 'forest degradation' has been widely used to describe a decrease in forest quality. However, the term has different interpretations, and therefore understanding of its definition and scope is necessary before conducting assessments of forest degradation. Grainger (1993, in Lambin, 1999) defined forest degradation as a process leading to temporary or permanent deterioration in the density or structure of vegetation cover or its species composition. Forest degradation is defined by Global Forest Watch (GFW) as a reduction in tree density and/or increased disturbance to the forest that results in the loss of forest products and forest-derived ecological services (FWI/GFW, 2002).

Assessment of forest degradation relates closely to sustainable forest management or forest resource use. To estimate the level of degradation in forested areas, the appropriate indicators for the assessment need to be determined. As indicated by the definitions above, important variables in evaluating forest degradation fall into two groups: tree primary production (woody biomass) and species diversity.

2.1.2 Remote sensing techniques for forest assessments

Geo-information technology, such as remote sensing, has been widely applied in land cover and forest cover change studies. Remote sensing allows quick and efficient monitoring over large areas of the earth's surface. The use of satellite imagery from two or more dates allows the assessment of changes in land / vegetation cover. One type of imagery commonly used for many earth surface applications is Landsat Thematic Mapper (TM) produced by National Aeronautics and Space Administration (NASA) (NASA, 2007). Landsat TM imagery has a spatial resolution of 30 m with 7 spectral channels, ranging from 0.45-0.69 µm in the visible spectrum and 0.76-2.35 µm in the infrared spectrum. Each band represents different wavelengths used to capture features on the earth surface (Lillesand and Kiefer, 1994). Due to these spatial and spectral characteristics, Landsat TM is an effective and widely used imagery source for mapping and monitoring land cover and vegetation.

2.1.2.1 Application to forest cover change and degradation

Remote sensing techniques to detect change dynamics in forests have been developed by many and can be divided into two approaches, post-classification time series analyses and image differencing.

The post-classification approach involves individual classification of each image in a time-series and then comparison of the generated thematic maps. This has been a popular method pursued in many studies, although criticism has also been directed to such methods. This approach has the risk of uncertainty in the semantic process of labelling the land cover or vegetation cover type. Many argue that when using multi-date multi-sensor images, the post-classification comparison method could lead to wrong results due to the differences in the radiometric characteristics of the images from which thematic maps were obtained, and errors brought from the individual processing of each of the images (Paolini *et al.* 2006; Foody, 2002). Despite the subjectivity, post classification comparison was found to be most accurate for old date images with different image acquisition dates/seasons (Mas, 1999).

Post-classification comparison for change detection is not recommended for detecting land modification (such as forest degradation) as it can lead to significant error in estimates of forest change (Foody, 2003). Image differencing refers to time series analyses of a set of geometrically and radiometrically corrected imageries, to obtain the residual values which show changes to the reflectance of respective pixels (see section 2.2.2 for further explanations).

2.1.2.2 Remote sensing and tree biomass estimation

The variables to be assessed using a remote sensing approach need to fulfill the basic principle that they represent biophysical attributes which can be assessed as surface characteristics measurable from space (Lambin, 1999). Lambin suggests that those characteristics assessable by remote sensing are vegetation cover, biomass, surface moisture and landscape heterogeneity. In line with that, Foody (2003) suggested that remote sensing applications for sustainable resource management include variables of, among others, land cover dynamics, vegetation biomass, biodiversity and vegetation disturbance.

Much work has been undertaken to determine the relationships between tree biomass measurements in a forest environment and optical satellite image attributes to estimate tree biomass at a landscape scale (Foody *et al.*, 2001 & 2003; Steininger, 2000; Nelson *et al.*, 2000; Zheng *et al.*, 2004; Lu, 2005,). There are mainly two groups of approaches in investigating the relationship between forest biomass and satellite image attributes; the first group uses mainly spectral information, while the second includes spatial structure of the image.

The application of spectral information for building a relationship with field biomass measurements uses satellite image attributes of spectral reflectance, image radiance, band ratios and/or vegetation indices. Multiple regressions are commonly applied to get the best fit model (Roy and Ravan, 1996; Zheng *et al.*, 2004; Steininger, 2000; Lu, 2005). Previous studies produced varied strengths of relationship and reported different image attributes and combinations as the strongest predictor variables for tree biomass estimation. That implies that the models developed are not robust and they fit only the characteristics of the sites where they were developed, e.g. the stage of forest regeneration, the dominant species, species heterogeneity/homogeneity.

Integration of spatial structure of the remotely sensed data has produced improved relationships when image texture (Nelson *et al.*, 2000; Lu *et al.*, 2004; Lu and Batistella, 2005) or spatial heterogeneity (Lambin, 1999) were incorporated in the models. Lambin (1999) argues that spatial structure represents more long-term patterns compared to spectral data which is more representative of inter-annual variability of the primary productivity.

The Lambusango area has been undergoing changes in land cover and its forest has been undergoing disturbance, as mentioned in Chapter One, section 1.1.6. For forest in particular, both conversion and degradation have taken place due to human activities. This chapter focuses on the dynamics of land cover change, forest degradation and forest structure utilising remote sensing approaches. The objectives of the work reported in this chapter are:

1. To quantify the extent of forest area loss in Lambusango and describe the dynamics of land cover changes within and at the periphery of Lambusango forest
2. To initially assess forest structure across rattan harvesting areas in different sites in Lambusango forest using tree above-ground biomass measures
3. To obtain a relationship between satellite image attributes and tree above ground biomass to estimate forest structure across the broader landscape

2.2 Methods

2.2.1 Satellite imagery data set and pre-processing

The study site and extent have been described in section 1.4.2. The imagery analysed in this study is Landsat Thematic Mapper (TM) data. The advantages of using Landsat TM lie in its global coverage, frequent capture of approximately every 16 days and the reasonable price. However, frequent cloud cover over Buton limits the number of useable images. For this study, imagery from three time periods was used for the change analyses (Figure 2.1). They are:

1. Landsat TM, 29 December 1991
2. Landsat TM, 14 November 2004

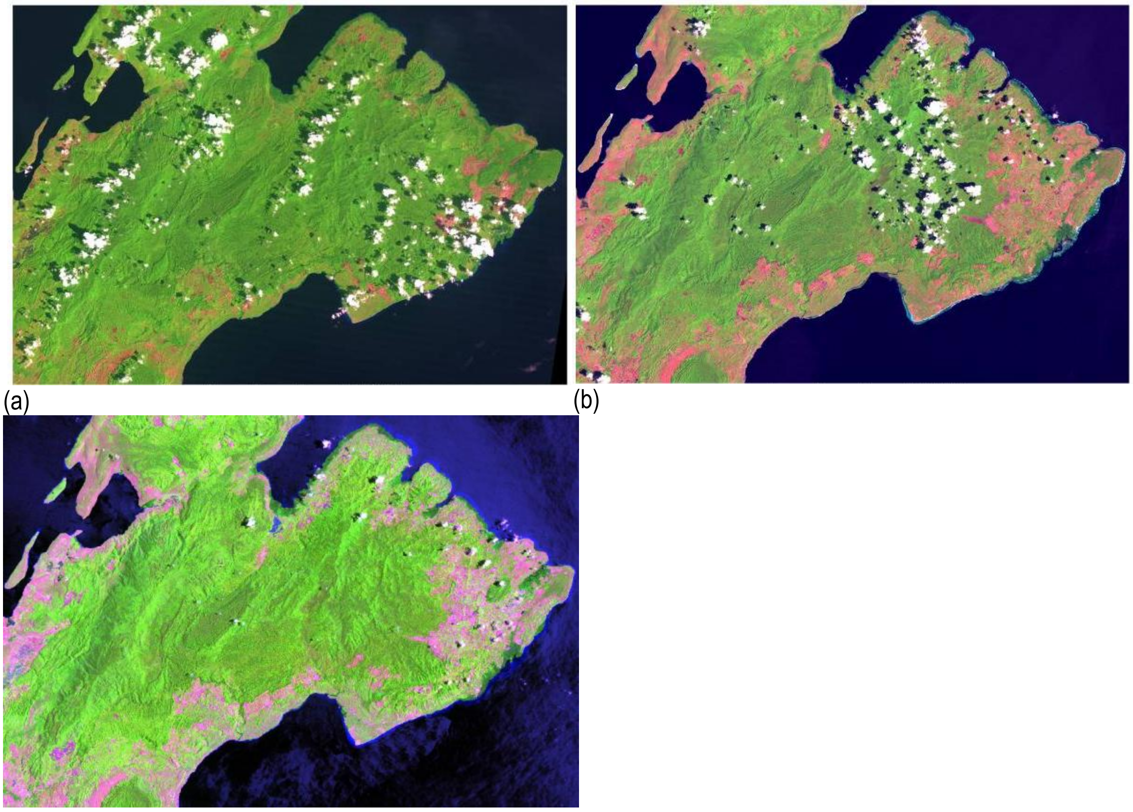
3. Landsat TM, 20 October 2006

Prior to image differencing, image radiometric and atmospheric corrections are at times necessary, although not all change detections need atmospheric correction (Song *et al.*, 2001; Paolini *et al.*, 2006). Atmospheric corrections are especially necessary for the Normalised Difference Vegetation Index (NDVI) and band ratios since atmospheric effects contaminate the signals of NDVI and the band ratio, and the modification is nonlinear (Song *et al.*, 2001).

Two types of corrections are explained briefly below: radiometric and geometric corrections

Radiometric correction

Raw, remotely sensed data captured by a satellite, provide information about objects' reflectance at the surface of the earth, which is scaled to a range of numbers called Digital Counts (DC) or Digital Numbers (DN). Along with the scaling process, some distortion is caused by atmospheric scattering, variation in viewing angle, scene illumination, and instrument response characteristics (Lillesand and Kiefer, 1994; Chavez, 1996). The objective of radiometric correction is to remove these radiometric distortions. Procedures, parameters and constants for correcting landsat TM images used in this study followed Chander and Markham (2003), and were applied using PCI Geomatica 9.1 image processing software.



(c)

Figure 2.1. Landsat TM imageries of (a) 1991 (b) 2004 and (c) 2006 - in 5-4-3 band combination

Geometric correction

Raw satellite images usually contain geometric distortions, and the sources of distortions range from variations in altitude, satellite attitude, and velocity of the sensor platforms, to factors such as panoramic distortion, earth curvature, atmospheric refraction, relief displacement and non-linearities in the sweep of a sensor's IFOV (Instantaneous Field of View) (Lillesand and Kiefer, 1994). The distortions can be corrected by establishing a mathematical relationship between pixels in the image and the corresponding coordinates of those pixels on the ground. All Landsat images were corrected using a linear polynomial geometric correction function with reported accuracies of 1.11 pixels, 1.53 pixels and 0.53 pixels for 1991, 2004 and 2006 respectively.

2.2.2 Forest cover and vegetation changes

In most cases, as in this study, land cover (change) analyses are highly related to vegetation analyses, since the major land cover types of concern are vegetation covers ranging from forest to intensive agricultural lands.

For vegetation mapping, spectral reflectance across the spectrum is characterised by peaks and valleys, dictated by chlorophyll absorption and reflectance. In the visible spectra, chlorophyll strongly absorbs electromagnetic energy and reflects little. In the near-infrared portion (0.7-1.3 μm) of the spectrum, the reflectance of healthy vegetation increases dramatically. The near-infrared reflectance increases with the number of leaf-layers in a canopy, to a maximum of eight leaf layers (Lillesand and Kiefer, 1994).

Vegetation change detection with image differencing is usually preceded by transforming the images using techniques such as Principal Component Analysis (PCA), NDVI (Huang *et al.*, 2000; Song *et al.*, 2001) or calculating the band-ratios (Huang *et al.*, 2000; Song *et al.*, 2001; Liu *et al.*, 2005). However, at times simple differencing of the particular bands has also been conducted, usually with TM band 3 or 4 (red and Near Infra Red (NIR) respectively) due to their sensitivity to vegetation changes. Image differencing of the red band is considered better than NIR and NDVI differencing (Huang *et al.*, 2000); while for burnt forest analyses NDVI differencing is considered best (Lee *et al.*, 2002), and NIR band differencing is best for vegetation succession in coniferous forest (Liu *et al.*, 2005). The continuum of output values need predefined thresholding for “change” and “no change” and commonly statistics derived from the resultant image, e.g. standard deviations, are applied (Lee *et al.*, 2002; Liu *et al.*, 2005). The determination of the best spectral variables and the thresholding values can be guided by accuracy assessment using groundtruth data.

The dynamics of the visible and infra red spectral response against vegetation density can be represented by a 'vegetation index'. This simple mathematical combination of the Red band and NIR band has been found to be a sensitive indicator of the presence and condition of green vegetation (Lillesand and Kiefer, 1994). A common vegetation index that is used in this study is the Normalized Differences Vegetation Index (NDVI).

The NDVI measures the slope of the line between the origin of red-NIR space and the red-NIR value of the image pixel. NDVI is calculated using the formula:

$$NDVI = \frac{NIR - Red}{NIR + Red} \qquad (2.1)$$

where *NIR* = value of near infra red channel;
Red = value of visible-red channel

NDVI values range from -1 to 1. A value of -1 to 0 is assumed to represent non-vegetated pixels. For easier calculation and interpretation, in this study, NDVI was scaled to a percentage with the lowest original NDVI value of non-vegetated area (-1) presented as 0 and the highest value (1) as 100.

The cloud-covered and shadow-covered areas were masked out from the images of the beginning year of observation (T_1) and the end year of observation (T_2) during the differencing process. A cautious threshold was used so that no un-clouded or un-shaded areas were included in the mask. However, this did mean that some cloud and shadow was omitted from the mask and remained in the change detection analysis.

To calculate the changes in vegetation density from 1991 to 2004 and 2004 to 2006, NDVI was calculated for the radiometrically corrected images and image differencing was then applied to calculate the change in NDVI values between T_1 and T_2. Constant NDVI values (i.e. 'no change') would result in zero in the change-map. Increases and decreases of NDVI values show the directions of vegetation changes, i.e. 'growth' or 'degradation'. Liu *et al.* (2005) set 1.5 standard deviations from zero as the threshold for 'changed' pixels, but gives no justification for choosing this threshold. Here, 0.5 standard deviations from zero was used as the threshold for changed pixels. This represents a cautious approach that should identify all changed areas, but may also include non-significant variation of NDVI that does not represent any meaningful land cover change. Hence, the NDVI-change image was then assigned classes:

1. growth : > (zero + 0.5*StDv)
2. no change : zero ± 0.5*StDv
3. degradation : < (zero - 0.5*StDv)

The 'degradation' class represents a variety of types of vegetation density decrease, ranging from forest clearing to preparation of shrubby vegetation for agriculture. Similarly, 'growth' represents forest canopy growth, canopy growth in the tree-based farming systems, or the growth of shrubby vegetation in agricultural land.

Observation of the changes across different forest zones was achieved by overlaying the vegetation change map on the designated forest zone map (see Chapter One, section 1.4.1 and Figure 1.4 for designated forest zone discussions).

2.2.3 Land cover classification and land cover change

2.2.3.1 Survey for groundtruth data

Field data collection involved visiting various land cover (LC) types in the study area and taking the GPS position for each sample. The groundtruth survey was conducted in 2006. For each LC type, notes were taken on the approximate age, canopy cover (for tree), approximate area of the parcel, and other environmental aspects observed in the field.

The groundtruth data, however, could only be directly used as training samples for classifying the most recent satellite imagery, i.e. 2006. To classify the earlier images of 2004 and 1991, the spectral reflectance information of the classes from 2006 was extracted and training samples for the earlier images were built based on those values.

With the objective of assessing forest degradation, forest was classified into three classes: near-primary forest, degraded forest and mangrove forest. The complete land cover classification is as follows:

1. Inland near- primary forest
2. Mangrove forest
3. Degraded forest, secondary growth
4. Tree-based farming systems
5. Non-tree crops, herbaceous vegetation
6. Inundated areas, paddy ricefield
7. Cleared land, bareland
8. No data consisting of : tidal areas, sea and water, shadow and cloud cover

Detailed description of each land cover type and pictures are shown in Appendix 1.

2.2.3.2 Image classification

Land cover classification refers to the automatic categorisation of the pixels in an image into land cover classes (Lillesand and Kiefer, 1994). When categorisation is performed using a set of training areas to guide the classification process, the classification is called *supervised classification*. The **maximum likelihood** classifier was used as the decision rule. This classifier assigns a pixel to a land cover category based on the highest probability value (Lillesand and Kiefer, 1994), and therefore is considered optimum.

2.2.3.3 Land cover change analyses

The land cover maps and the changes shown are used to complement and explain the types of land cover changes implied by vegetation density changes described in the previous section. Taking advantage of the more meaningful labeling of the classes derived from the ground truth samples, land cover maps can be used as a surrogate to describe the local land utilisation patterns. This allows interpretation of the type of land management systems being employed, for example, converting forest to crop farming systems.

2.2.4 Relationship of satellite image attributes to tree above ground biomass (AGB)

These analyses aim to observe the relationship between satellite imagery's pixel values and tree above-ground biomass (AGB). The relationship was applied to the most recent data set, i.e. 2006 Landsat TM. Two major activities were involved: estimation of tree AGB utilising forest inventory data and image transformations to obtain the attributes to relate to the AGB.

2.2.4.1 Estimation of forest tree AGB

Tree structure incorporates both the amount, or abundance, and height of trees. The amount of vegetation can be measured in various ways, most commonly with measures of density, cover, frequency and yield/biomass (Willis, 1973). *Density* is the number of individuals per unit area; *cover* is the proportion of ground covered by a species usually presented as a percentage; *frequency* is the chance of finding a species in any area; *yield* is a measure of the amount of plant material in dry weight (Willis, 1973). This study applies a measure of yield or biomass to relate to the satellite imagery's attributes.

Tree biomass is a product of tree primary production and forms the major above-ground biomass. It plays a key role in sustainable management and in estimating forest carbon stocks. Tree AGB is usually derived from empirical equations using measurements of tree dbh (diameter at breast height or equal to 1.3 m above ground). The most common mathematical model is a power function $B=aD^c$ where a and c are allometric coefficients derived from empirical data, and B is the total aboveground tree dry biomass for a specific dbh (D) (Ketterings *et al*, 2001; Foody *et al.*, 2001; Zianis and Mencuccini, 2004). Different equations have been presented for specific tree species and environments, calibrated using destructive sampling and the plants' dry weights (Brown, 1997; Ketterings *et al*, 2001; Zianis and Mencuccini, 2004). Several allometric equations have been suggested for humid tropical forests, a list of which is summarized by Zianis and Mencuccini (2004). The most widely used equation is from Brown (1997), but some argue that, for example, for secondary forest and fast growing species in Indonesia this equation overestimates biomass (Hairiah *et al.*, 2001) and thus an alternative equation was proposed (Ketterings *et al.*, 2001).

In this study tree biomass was estimated using the allometric equation proposed by Brown (1997; Equation 2.2), which was built empirically for moist tropical forest and has been applied in several other locations in the tropics including Borneo, Thailand and the Amazon (Foody *et al.*, 2001).

$$B = 0.118D^{2.53} \tag{2.2}$$

where *B* = Tree biomass expressed in Mg ha^{-1}, *D* is diameter at breast height (dbh) in cm.

2.2.4.2 Data collection for AGB estimation

Sample plots were established in 2006 by following rattan trails that had been mapped in 2005. Sample plots were located in relation to these rattan trails. While the general location was based on information given by the local guide, the precise choice of location was arbitrary. The plots were orientated perpendicular to the trails and along the slope gradient. This was considered to accommodate a cross section based on the distance from the walking trail as well as the profile from ridge-top to valley-bottom (Figure 2.2). The number of plots for each site is presented in Table 2.1.

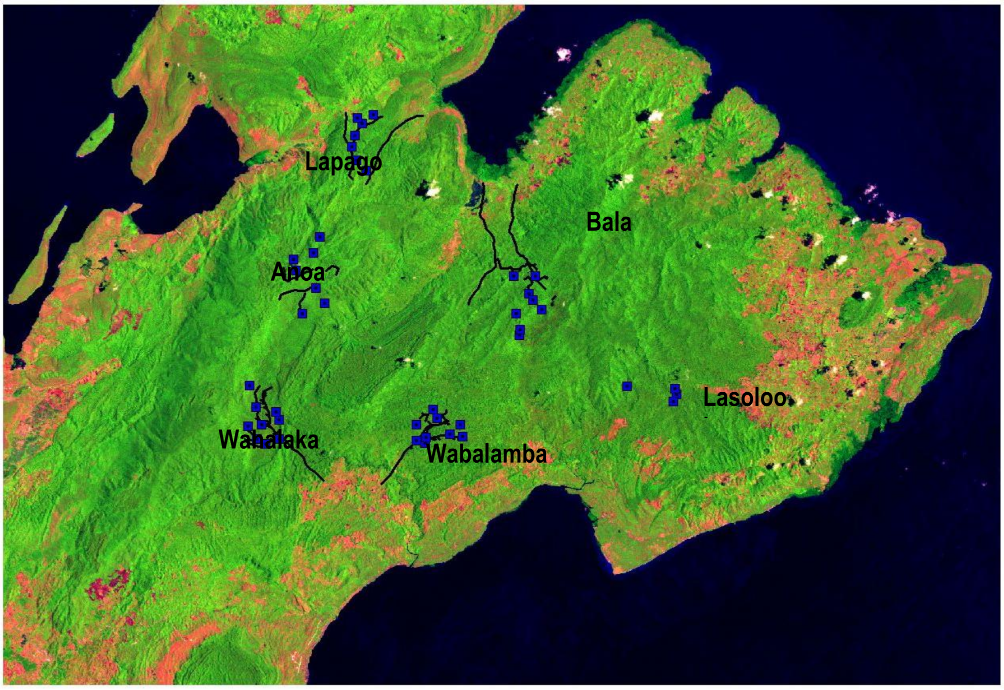


Figure 2.2. Rattan trails and the sample plots in the study area

Table 2.1. Forest sample plots at each site

Site	Number of plots
Wabalamba (WB)	9
Wahalaka (WH)	9
Anoa (AN)	7
Bala (BL	8
Lapago (LP)	7
Lasolo (LS)	4
Total Plots	44

50 m * 10 m plots were established, consisting of five quadrats of 10 m * 10 m, following methods established in the years preceding this PhD study (Carlisle, in progress). Due to micro relief, the 50 m length generally covers well the entire slope from ridge-top to valley-bottom. Tree structure measurements were taken in each quadrat. Other measurements were also taken and are described in the relevant chapters. The design and layout of the sample plots for the tree measurements relevant for this chapter are illustrated in Figure 2.3.

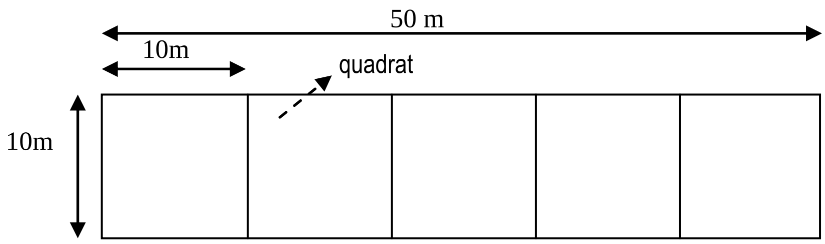


Figure 2.3. Design of sample plot for both rattan and tree inventories

All trees in the quadrat with > 5cm dbh were sampled and dbh and vernacular name were recorded. A Garmin 76S GPS was used to record the geographical location of each plot, taking the centroid of the third quadrat (mid-quadrat) as the plot position.

2.2.4.3 AGB estimation outside forest

Since there are no plot measurements outside the forest in this study, secondary published information was used to establish the relationship between remotely sensed image attributes and AGB in non-forest land cover types. The AGB reference was based on a study conducted in Nunukan District, East Kalimantan, Indonesia (Rahayu *et al.*, 2005), and the similarity in land cover types was used as the basis to calculate AGB for non-forest areas.

Table 2.2. AGB reference for various land cover types from Rahayu *et al.* (2005)

	Land cover categories	AGB (Mg ha^{-1})[2]
1	Complex Agroforestry/homegardens	161.33
2	Mature Tree-based farming systems	83.78
3	Secondary forest, woody shrubs	128.89
4	Newly opened cropland	43.11
5	Grass and herbaceous	9.33

Eleven non-forest points in the areas surrounding Lambusango forest were chosen based on the landcover groundtruth survey and included in the analysis.

[2] 1 Mg = 10^3 kg

2.2.4.4 Relationship between tree AGB and satellite imagery properties

The satellite imagery used in these analyses is the radiometrically and geometrically corrected Landsat TM acquired on 20 October 2006. Various spectral and spatial image attributes are used in this study, and they are grouped into spectral attributes and spatial attributes (Table 2.3).

Table 2.3. Spectral and spatial attributes extracted from Landsat TM imagery

Spectrally-derived attributes	Spatially-derived attributes
- Original spectral reflectance – with the mean value of 3*3 windows to take into account GPS positional error - Band ratios and vegetation indices - Transformed bands	Image texture measures

To avoid an excessive number of attributes, attempts to narrow down the possibilities were made by first analysing the correlation among satellite image bands and also by selecting the bands known to have strong correlations with vegetation biophysical properties, bands 4 and 5. Furthermore, similarity to previous similar studies by Lu *et al.* (2004) and Lu (2005) was also considered. Table 2.4 lists the image attributes extracted from landsat TM imagery and the transformations applied to obtain those attributes are described briefly below:

Principal Component Analysis (PCA) is a transformation of the spectral bands in order to reduce the spectral values redundancy across multispectral bands such as in Landsat TM. It is conducted primarily because of the problems of interband correlations in multispectral image data. The new extracted values to be used are linear combinations of the original data values and the biggest variations are contained in the first principal component layer, while the second principal component layer contains the residual from the first, and so on (Lillesand and Kiefer, 1994). The transformed images to be used further in the following analyses are PC1 and PC2.

Tasseled cap transformation is a specific transformation of multispectral bands such that the majority of information is contained in the two components of brightness and greenness, the first one being related to the principal variation in soil reflectance, while the second is strongly related to the amount of green vegetation (Lillesand and Kiefer, 1994). An extension of this method resulted in a third component, namely wetness, which relates to canopy and soil moisture (Lillesand and Kiefer, 1994). These three indices are commonly used for vegetation monitoring purposes.

Texture analysis is an image transformation which extracts spatial variation in pixel intensities or gray values of the image’s pixels (Tuceryan and Jain, 1998). There are a number of texture measures which may be applied to an imagery data set, including: contrast, dissimilarity, mean, variance and correlation (PCI Geomatics, 2007). These measures were applied to the individual bands of TM band 4 and TM band 5, and using different window sizes of 3*3, 5*5 and 9*9 pixels.

Table 2.4. Satellite imagery derived attributes applied in this study

Group	Attribute	Abbreviation	Remarks
Spectral reflectance	Mean of Reflectance	Bx_refl	For each band : 1,2,3,4,5,7; mean of 3*3 window size
Band ratios	TM4/TM3	TM43	
	TM5/TM3	TM53	
	TM5/TM4	TM54	
	TM4/TM7	TM47	
Vegetation Indices	NDVI	NDVI	(TM4-TM3)/(TM4+TM3)
	Normalised difference of TM5 and TM3	ND53	(TM5-TM3)/(TM5+TM3)
	Normalised difference of TM5 and TM4	ND54	(TM5-TM4)/(TM5+TM4)
	Normalised difference of TM3 and TM2	ND32	(TM3-TM2)/(TM3+TM2)
	Normalised difference of TM7 and TM5	ND75	(TM7-TM5)/(TM7+TM5)
	Normalised difference of TM7 and TM4	ND74	(TM7-TM4)/(TM7+TM4)
Transformed bands	Tasseled cap – brightness	KT1	0.3037(TM1) + 0 .2793)(TM2) + 0.4743 (TM3) +0.5585 (TM4) + 0 .5082 (TM5) +0.1863 (TM7)
	Tasseled cap – greenness	KT2	-0.2848 (TM1) - 0.2435 (TM2) - 0.5436 (TM3) + 0.7243 (TM4) + 0.0840 (TM5) - 0.1800 (TM7)
	Tasseled cap – wetness	KT3	0.1509 (TM1) + 0.1973 (TM2) + 0.3279 (TM3) +0.3406 (TM4) - 0.7112 (TM5) - 0.4572 (TM7)
	Principal Component 1	PC1	
	Principal Component 2	PC2	
Texture	Contrast	Con	Textures are applied to:
	Dissimilarity	Dis	- Bands 4 and 5
	Mean	Mean	- window sizes: 3*3, 5*5, 9*9
	Variance	Var	e.g. b4text3_dis = texture measure of dissimilarity applied to band 4 and with
	Correlation	Corr	window size 3*3

The relationship between remotely sensed image attributes and AGB was defined by first extracting image attribute values at the sample points utilising the recorded GPS positions. Previous research indicated that a combination of spectral responses and textures improves tree AGB estimation performance compared to spectral responses or textures alone (Lu, 2005; Lu and Batistella, 2005). Correlations between each image attribute and each of the biophysical properties were sought using Pearson correlation.

Upon finding significant correlations, the best correlated attributes were selected. Multiple linear regressions were then conducted to observe the relationships between image-derived attributes with AGB of the forest plots and also with AGB of the entire samples of forest and non-forest plots. Prior to the regressions, data was checked for co-linearity among predicting variables and for data normality. Image attributes became the predicting variables and tree AGB was the response variable. Different variable selection procedures (enter, forward, backward and stepwise) were employed to produce different multiple linear regressions.

When producing several regression models, it is important to select the model which best describes the relationships in the data. Regression coefficients (R^2) and the Akaike Information Criterion (AIC) are commonly used to determine the most reliable model. AIC is a measure of how likely it is that a model is correct (Motulsky and Christopoulos, 2003). In applying AIC for model selection, first AIC scores are calculated for each model produced from a given data set applying different models, then the scores of different models are compared and the model with the smallest AIC is selected (see e.g. Lindsey, 2004).

When the number of observations is small in comparison to the number of parameters tested, the corrected AIC (AIC_c) is considered more accurate than AIC (Motulsky and Christopoulos, 2003). AIC_c was applied in this study and the best model was selected based on the smallest AIC_c.

The AIC and AIC_c calculations are based on the following equations (Equations 2.3 and 2.4) (Motulsky and Christopoulos, 2004):

$$AIC = \ln\left(\frac{RSS}{n}\right) + 2K \tag{2.3}$$

where K = number of parameters; RSS= regression residual sums of squares; n=number of observations

$$AICc = AIC + \left(\frac{2K(K+1)}{n-K-1}\right) \tag{2.4}$$

SPSS 9.0 and MS Excel were used for the statistical procedures and AIC calculations.

2.3 Results

2.3.1 Vegetation density changes 1991-2006

From the residual images, the NDVI change lies between values of -47 and +27 for 1991-2004, and between -49 and +46 for 2004-2006. The NDVI-change values approximate normal distributions, with a mean of -0.14, standard deviation of 6.5 for 1991-2004 and 0.14 and 4.6 for 2004-2006. The resulting maps of NDVI changes classed as degradation, no-change and growth in the two change periods are shown in Figures 2.4 and 2.5.

Within the extent of this study area, between 1991 and 2004, 24,000 ha (16% of total area) was degraded, 77,000 ha (52%) remained unchanged, and 23,000 ha (15%) experienced growth. Most of the degradation took place in the non-forest zone (72% of the total degraded area; Figure 2.4). The growth taking place during this period was relatively small, less than 10,000 ha for each designation zone, and shows no significant differences across forest designation zones. The Protection Forest zone can be neglected in the analyses due to its small area (total 2800 ha). The no-change class is dominant in this period, with the highest proportion in Conservation Forest (75%), followed by Production Forest (73%) and then the Non-forest zone (46%).

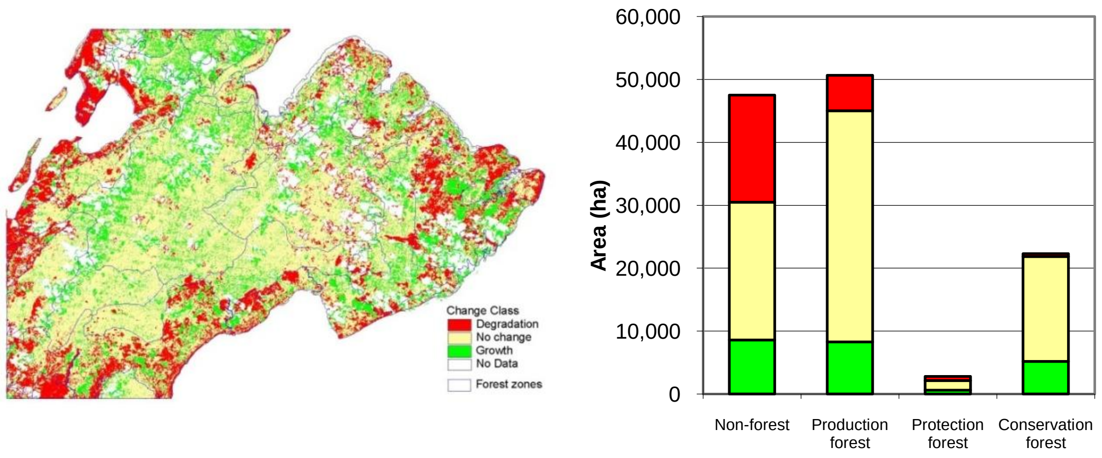


Figure 2.4. Vegetation density change across designated forest zones, 1991-2004

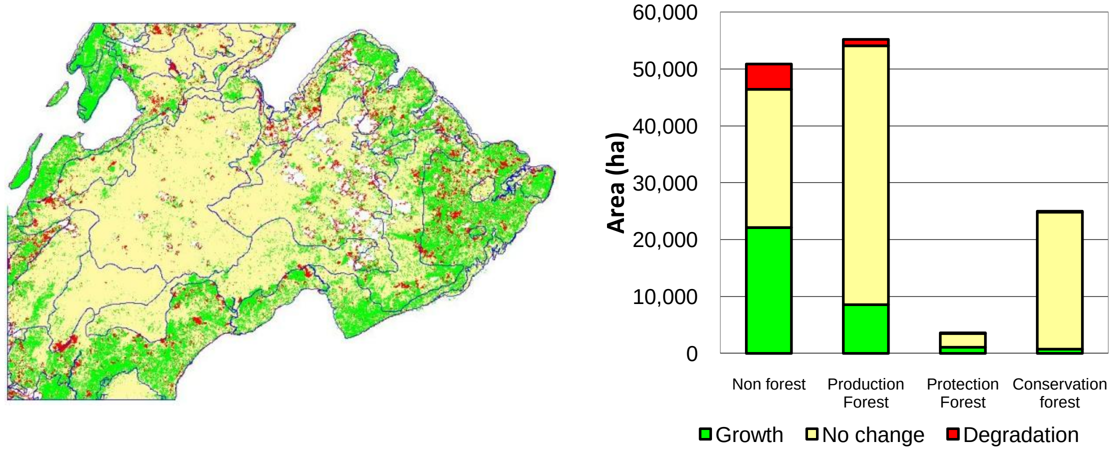
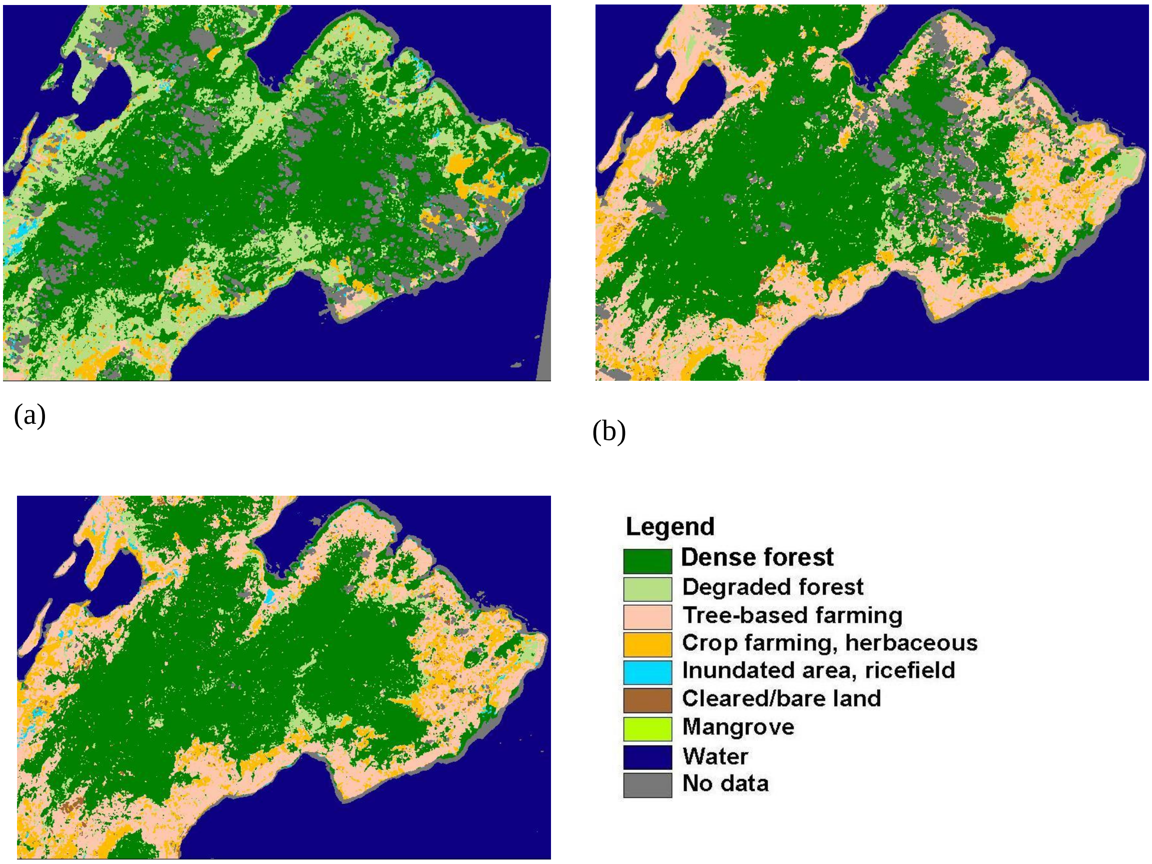


Figure 2.5. Vegetation density change across designated forest zones, 2004-2006

Between 2004-2006, for the whole study area, degradation took place in only 5,900 ha (5%), no-change in 96,000 ha (64%) and growth in 34,000 ha (22%) (Figure 2.5). In 2004-2006 growth exceeds degradation in each designation zone. Growth occupies 22,000 ha (43%) of the Non-forest zone, 8,500 ha (15%) of the Production Forest and 730 ha (3%) of the Conservation Forest. Similar to the preceding period, the no-change class is dominant in all designation zones, with the highest proportion in Conservation Forest (96%), followed by Production Forest (82%) and the Non-forest zone (48%).

2.3.2 Land cover changes 1991-2006

The resulting land cover maps of 1991, 2004 and 2006 are shown in Figure 2.6, and full size maps can be seen in Appendix 2.



(c)

Figure 2.6. Land cover maps of (a)1991, (b)2004 and (c)2006

In line with the changes in vegetation density in the 1991-2004period, the landcover maps of 1991 and 2004 show that development of agricultural areas, i.e. tree-based farming systems and crop farming, took place largely in the areas surrounding Lambusango forest, which were mainly covered with secondary forest growth/shrubby vegetation in 1991. The core forest did not show significant changes except for small patches which can be considered negligible.

From 2004 to 2006, the land cover types do not show significant changes. The emergence of inundated areas in 2006 which were mainly crop farming systems in 2004 is most likely due to the inter-annual variability of ricefield farming systems captured by the satellite imagery.

Figure 2.7 summarises the land cover changes in the study areas.

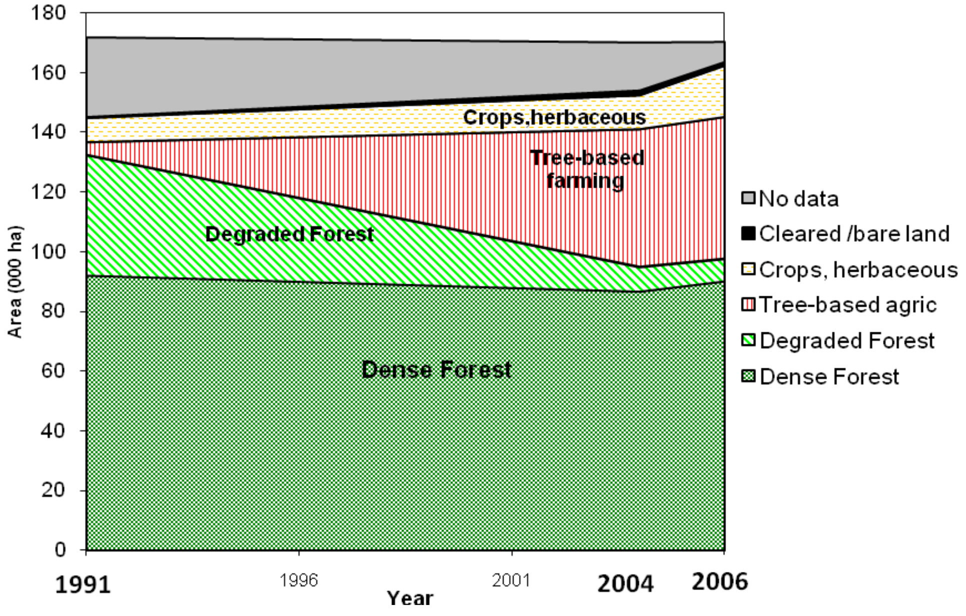


Figure 2.7. Change in areas of land cover types from 1991 to 2006

2.3.3 Tree above ground biomass (AGB)

2.3.3.1 Tree AGB calculation

The AGB calculation for each site is summarised in Table 2.5 and Figure 2.8.

Table 2.5. Average tree AGB for the six sites

No	Site	Nbr of plots	Tree AGB per plot (kg per plot)	Tree AGB per site (Mg ha^{-1})
1	Wabalamba	9	20,895	418
2	Wahalaka	9	18,263	365
3	Anoa	7	14,972	299
4	Bala	8	14,924	298
5	Lapago	7	11,820	236
6	Lasolo	4	16,636	333

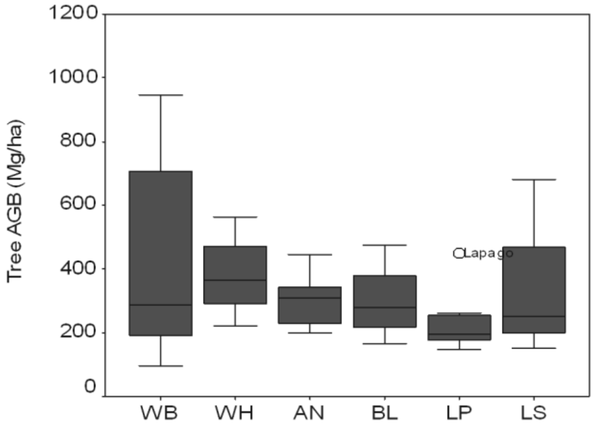


Figure 2.8. Average tree AGB for each of the six sites

Wabalamba has the highest average AGB per hectare (418 Mg ha^{-1}) and Lapago has the smallest average value (236 Mg ha^{-1}). Wabalamba also has the highest variation as it has both the plots with highest average AGB (945Mg ha^{-1}) and with the lowest in the study area (96 Mg ha^{-1}). Wabalamba site is located in the Production Forest zone and has been one of the main sites of logging activities. The high tree AGB might be best explained by the fact that this area houses tree species with large diameters compared to other areas, perhaps due to the flat topography and low elevation, and thus attracts timber extraction activities. The lowest figure may be due to that particular plot being located in a heavily logged area.

2.3.3.2 Relationship between tree AGB and satellite image attributes

For the 44 forest plots, the best regression model was achieved with the texture measure of correlation of band 5 with a 5*5 window (b5text5_corr), although the R^2 is low 0.1163 (Figure 2.9).

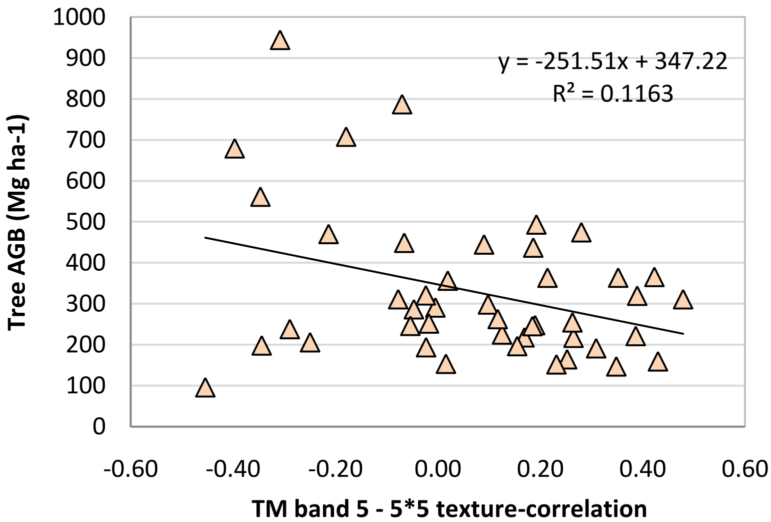


Figure 2.9. Regression of tree AGB and Landsat TM band 5 correlation texture measure with a 5*5 window

When taking into account the 11 non-forest points in addition to the 44 forest points, an improved relationship was obtained. The relationship between spectral responses and AGB is usually curvilinear (Foody *et al.*, 2001), and therefore an exponential model was sought. The best predicting variable for AGB is the mean reflectance of band 5 (b5_refl) with an R^2 of 0.72 (Figure 2.10).

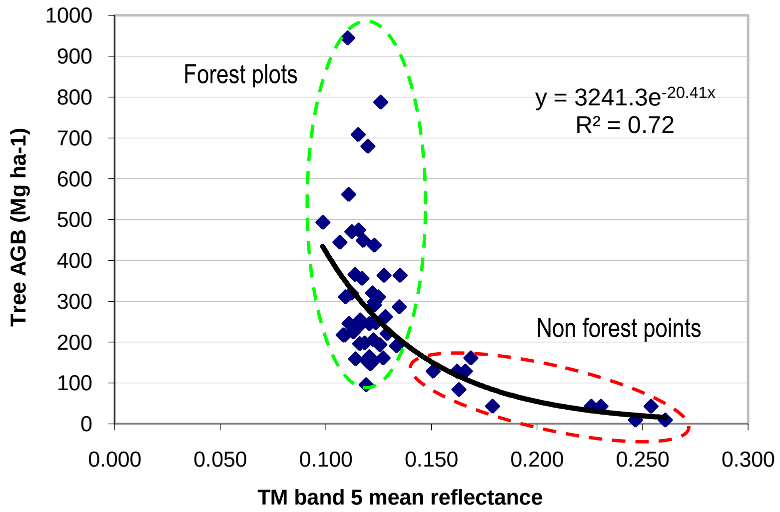


Figure 2.10. Regression between tree AGB and Landsat TM - mean reflectance of band 5

Figure 2.10 shows that with the 11 non-forest points included in the regression, a good relationship between spectral reflectance and above ground biomass could be established. It is clear that the decrease of reflectance in TM band 5 has a good relationship with the increase of tree AGB down to approximately reflectance values of 0.13, while below that value, the spectral reflectance shows little variation while the woody biomass keeps increasing, from 150 Mg ha^{-1} up to 944 Mg ha^{-1}.

2.3.3.3 Regressions for combinations of Landsat TM image-derived attributes

Based on the forest sample plots, the image attribute with the best correlation is 'B5text5_corr' (R=0.341). Only attributes with R > 0.25 were further tested, which are: 'B5text5_corr', 'ND54' and 'B1rflmean3'. The best multiple regression model used the enter or backward variable selection procedure:

*AGB= 3222.02-(1421.1*ND54)-(223.9*B5text5corr)-(27518.6*B1rfl)*

(with R^2 = 0.237, Adjusted R^2 = 0.180, F statistics= 4.147, df= 3, *p=0.012* and AIC_c score = 456.253)

(Notes: see Table 2.4 for explanations of abbreviations. Statistics and the AIC_c scores of the tested models are shown in Table A3.1, Appendix 3.)

For forest and non-forest plots, Landsat TM image-derived attributes that show high correlations with AGB (R>0.51) are 'B5text3_mean', 'B5text5_mean', 'ND32', 'PC1', 'KT1' and 'B5rfl' (see Table 2.4 for explanations of abbreviations). Attempts to conduct multiple linear regression between image-derived attributes and AGB were not pursued, because it was found that co-linearities among predicting variables are high (R≥0.7), which means the predicting variables are inappropriate for multiple linear regression (e.g. in Foody *et al*, 2001).

2.4 Discussion

2.4.1 Land cover and vegetation changes in Lambusango area

Agricultural extension took place in the first period (1991-2004) at the expense of forested areas which were still extensive in 1991. Tree crop farming is popular with the local farmers around Lambusango forest, and they commonly plant cashew, coconut, and teak. Intercropping with coffee and cacao is also common in some areas. In the subsequent period, 2004-2006, vegetation density increased in those farming areas as a result of tree growth, and in some cases many tree-crop gardens were left by the owners and developed denser shrubby vegetation. The different forms of tree-based farming systems can be potentially beneficial as a buffer at the forest edge. A study of the Sulawesi cacao agroforestry environment showed that the transformation from near-primary forest to agroforestry only caused minor quantitative changes in biodiversity and it maintained high levels of ecosystem functioning while doubling farmers' net income (Steffan-Dewenter *et al.*, 2007).

The two change periods analysed here are not directly comparable due to the large difference in the observed durations, 13 years and 2 years. The micro-temporal dynamics within the first period are not well represented in these analyses. However, by simply converting to an annual rate of degradation, the extensive total degradation taking place during 1991-2004 is actually a lower annual rate compared to that in 2004-2006, i.e 1800 ha yr^{-1} in 1991-2004 and 2900 ha yr^{-1} in 2004-2006. This implies that despite the major growth taking place in the areas surrounding the forest in 2004-2006, degradation and forest clearance still takes place, and this might occur at a potentially more alarming rate at present and in the near future compared to that in 1991-2004.

From the dynamics that occurred over the 15 years, it is shown that despite the extensive changes from more natural forest cover to man-made agricultural systems, both crops and tree-based systems, the changes took place mainly in the secondary forest areas outside the core forest. The core forest areas stay relatively intact during the 15 year observation period. The dynamics of the non-forest areas after conversion are not well-represented with the available data and time series. However, it is clear that the option of tree-crop farming has been attractive to the local people.

Observing the dynamics of the 'dense forest' class, the slightly decreasing area between 1991-2004 and slightly increasing area between 2004-2006 have to be interpreted with caution. This may be the result of more clouds and shadows in the T_1 of each observation period compared to T_2. In 1991-2004 the actual forest cover loss is more likely larger than the figure shown, and in 2004-2006 forest cover might have slightly decreased rather than slightly increased.

2.4.2 Remotely sensed data and methods to estimate landscape AGB

Attempts to find a relationship between tree AGB and image attributes found Landsat TM band 5 to be most useful. The relationship was better defined when involving a wider range of vegetation densities including the non-forest areas. The predicting power in estimating AGB is better for reflectance values of 0.26 down to approximately 0.13. The higher the TM band 5 reflectance is, the sparser the vegetation density is. From the empirical data gathered in this study, the reflectance values of 0.13 - 0.14 are from secondary forest and mature tree-based systems. Below that value, down to a reflectance value of 0.1 represents reflectance from dense forest. In a forest environment, due to the closed canopy cover, spectral responses have been found to reach saturation while the woody biomass from tree primary production continues to increase (e.g. in Widayati *et al*, 2005). The increase in woody biomass up to 900 Mg ha^{-1} within that narrow low reflectance of TM band 5 shows that biomass estimation over larger areas based on this method and datasets will not be accurate.

Using the best-correlated image attributes, multiple regressions were tried to derive a relationship between a combination of satellite imagery derived attributes and forest AGB. However, due to the low correlations and low R^2 in the model established, and thus the expected high uncertainty of the resultant estimation, it has been decided not to pursue landscape estimation of tree AGB. Foody *et al.* (2001) argue that multiple regressions of image attributes should be applied with caution because it assumes a linear relationship between remotely sensed data and the tree biophysical properties, while in most cases they are curvilinear. Furthermore, multiple regressions assume that the predicting variables are uncorrelated while in fact satellite imagery bands are often correlated (Foody *et al.*, 2001), which was confirmed by the evidence from this study. Foody *et al.* (2001& 2003) proposed the use of alternative non-parametric multiple regressions such as artificial neural networks in which improved relationships between satellite image attributes and biomass were reported. However, due to the scope of this study and other limitations such as time and technicalities, no further attempts were pursued.

2.5 Summary and conclusion

Conversion of forest to other land cover types as well as conversion between non-forest types and some regeneration of forest took place in Lambusango and the surrounding landscape. This indicates the dynamic nature of the study area.

Forest loss to agricultural uses mostly took place in the Production Forest zone, which indicates that conversion was mainly from secondary forest rather than the near-primary forest of the core area. The Lambusango Reserve itself shows much less change than other zones.

Tree-crop farming has been attractive to the local villagers. The development and dynamics of this system must be investigated further to understand to what extent they can be considered a buffer zone and extension of the Lambusango Reserve.

When creating a mask of areas to exclude from the analysis due to cloud cover or shadow, a cautious approach was adopted to minimise the chance of un-clouded or un-shaded areas being included in the mask, and consequently potentially causing changes to be missed. However, this means that some areas of cloud and shadow have remained in the analysis, causing mis-identification in some areas and over-estimation of change. Countering this, there is the possibility that cloud or shadow masked out of the analysis could be obscuring areas of genuine change causing under-estimation.

There is wide variation in tree above ground biomass across the sites. Taking secondary/published information, above ground biomass of Indonesian forests ranges approximately from 320 to 600 Mg ha^{-1} (Murdiyarso and Wasrin, 1995, in Lasco, 2002) and that of Southeast Asian forests ranges approximately between 50-430 Mg ha^{-1} (Brown *et al*, 1991, in Lasco, 2002). Most of the sites in this study have levels of woody biomass within both of those ranges.

The relationship between tree AGB in the forest and satellite image derived attributes is asymptotic, so the variation in woody biomass cannot be explained by the remotely sensed derived information, and thus with the data set and methods applied in this study, accurate estimation is not possible.

Chapter 3. Species diversity and standing stock of rattans (*Calamus* and *Daemonorops*) and the associations with environmental and soil factors

3.1 Introduction

3.1.1 Rattan ecology

Rattans grow in a range of environmental conditions, including varying altitude, light conditions, soils and humidity (Rachman and Jasni, 2006). Previous studies indicate that several rattan species have altitudinal preferences, e.g. *Calamus flagellum* and *Daemonorops jenkinsiana* at 500-600 m asl (Ban *et al.*, 2005). Ban *et al.* (2005) found an accumulation of rattan species at 500-550 m asl, while Rachman and Jasni (2006) found the greatest number of species at approximately 600 m asl. Some species can adapt to a wide range of altitudes, e.g. *Calamus ceratophorus* Conrad is found from 500 m up to 1000 m asl (Ban *et al.*, 2005), and *Calamus symphysipus*, *Calamus zollingeri* and *Daemonorops robusta* are found at up to 1330 m asl (Siebert, 2005). At the extreme, rattan is considered to tolerate altitudes from 0 m asl up to 2900-3000 m asl (Dransfield and Manokaran, 1994; Rachman and Jasni, 2006). Watanabe and Suzuki (2008) state that rattans are less diverse and less abundant at higher altitudes, indicating reduced tolerance to lower temperatures. Knowledge of the influence of altitude on rattan distribution depends on the accuracy of species identification. As discussed by Siebert (2005), evidence from field inventories showing that some rattan local names are found at a wide range of altitudes may actually be due to the lack of or inaccurate botanical identification. It is likely that a common local name found at various altitudes actually refers to different species, each adapted to a certain altitude (Siebert, 2005).

Understorey light plays a role in the growing environment of understorey plants, such as rattans, subordinate trees and tree regeneration (Brown *et al*., 2000). Plants use part of the light spectrum for photosynthesis, known as PAR (Photosynthetically Active Radiation), which has wavelengths of 400-700 µm (Whitmore, 1990). Rattan species are adapted to a wide range of light conditions, ranging from full light to shaded forest understorey (Dransfield and Manokaran, 1994; Sunderland and Dransfield, 2002; Ban *et al.*, 2005). Several species are shade intolerant, and thus require canopy gaps for their growth and development, such as the commercial species *Calamus caesius* and *Calamus manan*, although a shaded environment is preferable for seedling establishment of most climbing rattan species (Dransfield and Manokaran, 1994). Studies of *C. zollingeri* and *C. caesius* show that they have contrasting light requirements, with *C. zollingeri* preferring a gap environment, while *C. caesius* grows well in a low light environment (Siebert, 1993). For rattans in East Kalimantan, van Valkenburg (2002) found evidence that juvenile and immature shoots are abundant in forest gap areas due to logging, while for mature canes, the absence of large trees in forest gaps to support climbing causes the canes to coil on forest floors, resulting in lower quality canes.

Soil characteristics and water availability are also considered important for rattan regeneration and growth (Nur Supardi *et al.*, 1999). Different rattan species are adapted to different soil moisture regimes, from swampy soils to dry ridge tops (Dransfield and Manokaran, 1994). However, Watanabe and Suzuki (2008) found evidence that poor drainage and swampy areas are unfavourable for rattans. Topographic characteristics affect water and moisture levels which influence rattan growth. Slope angle affects the equilibrium between weathering and denudation causing thinner and stony soils on steeper slopes and highly-weathered soils on gentle slopes (Young, 1976). This then affects productivity of the vegetation. Soil chemical properties and consequently available nutrients change with altitude (Siebert, 2005). For forest vegetation, Schoenholtz *et al.* (2000) noted that soil chemical properties commonly assessed as indicators of forest soil quality include: C, N, P, K, Cation Exchange Capacity (CEC), Ca, Mg, pH, salinity and Electrical Conductivity (EC).

Rattan plants are commonly categorised into two types: solitary plants with a single stem and clustering plants with multiple stems (Sunderland and Dransfield, 2002), although Rachman and Jasni (2006) also named branching clustering plants as a third type. Rattan stems can grow up to 100 m in length and therefore need strong supporting trees (Rachman and Jasni, 2006). However, several rattans are understorey species and the canes are non-climbers (Dransfield and Manokaran, 1994). Clustering rattan can reproduce vegetatively, while solitary rattan can only reproduce by flowering and fruiting, which restricts regeneration compared to the clustering counterparts (Siebert, 1993).

3.1.2 Rattans in Buton

In Indonesia, rattans grow in the forests of Sumatra, Kalimantan and Sulawesi and are mostly wild, except in Kalimantan where rattans have been cultivated by local farmers (Dransfield and Manokaran, 1994; Belcher, 2001/2). Lambusango is one of the forests in Indonesia where rattan is widespread. With altitude ranging from 0 m to approximately 700 m asl, rattan plants and clumps grow in almost every part of the forest. Little is known about rattan species composition, abundance and distribution in Lambusango forest, but scientific projects and inventories have been ongoing since 2000. So far, 17 rattan species have been identified and a few other local names are yet to be identified (Powling, 2009). Several rattan species are commercial and are widely harvested by local collectors living in the forest periphery, i.e. *Rotan Batang* (*Calamus zollingeri*), *Rotan Lambang* (*Calamus ornatus*), *Rotan Umbul* (*Calamus Symphysipus*), *Rotan Kabe* (*Calamus sp*) and *Rotan* Noko (*Daemonorps robusta*) (Purwanto, 2005a). The canes of these species are large diameter (*C. zollingeri*), medium diameter (*C. ornatus*, *C. symphysipus*, *and D. robusta*) and small diameter (*Calamus sp*.). There are several previous studies of *Calamus zollingeri* due to its commercial value, but very little for the other species.

The objective of this chapter is to assess the distribution and abundance of rattan species across Lambusango forest and the influence of soil and environmental conditions, with the focus given to common species and commercial species found in Lambusango forest.

Three research questions have been developed for this chapter, namely:

1. What is the distribution of different rattan species and how does species richness and dominance vary?
2. Which environmental factors and soil chemical properties best explain the presence and abundance of particular rattan species and rattan diversity in Lambusango forest, with the emphasis on commercial species?
3. Are abundance and distribution of rattan associated with tree and vegetation structure?

3.2 Methods

3.2.1 Sampling and data collection

3.2.1.1 Rattan trail and sample plots

A general study site description and overall sampling design were given in Chapter One and sample plots have been described briefly in Chapter Two (section 2.2.4.2). Figure 3.1 visualises the plot distribution in the study area. Plots were located in core and residual peripheral areas of rattan cane harvesting, with a few in the least harvested areas.

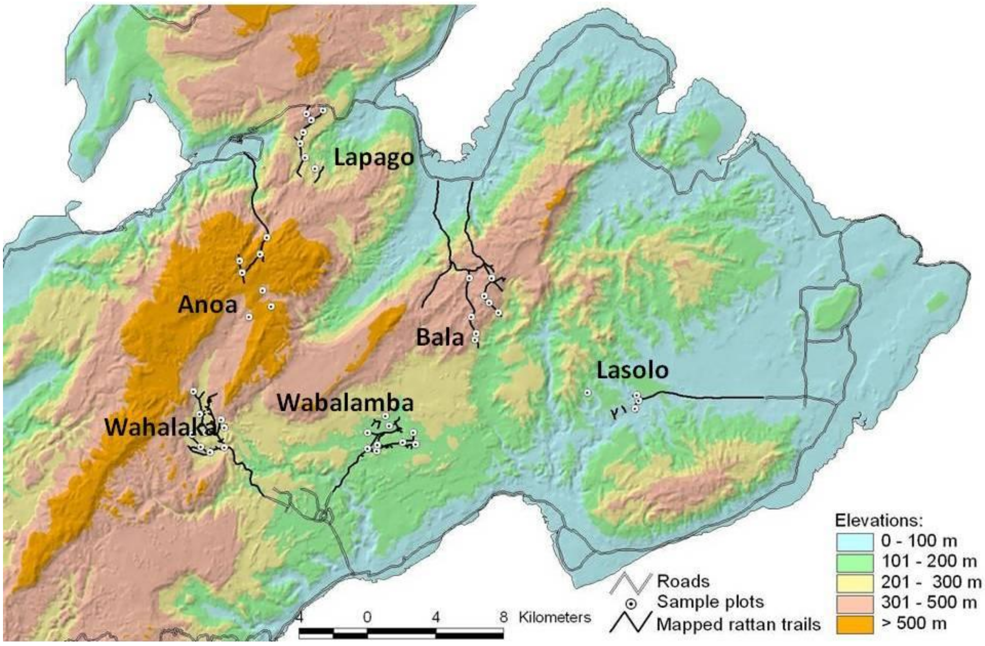


Figure 3.1. Mapped rattan trails and rattan sample plots in the six study sites

The rattan inventory used the same plots as for the tree measurements of Chapter 2 and soil samples were also taken. The design and layout of the sample plots are illustrated in Figure 3.2.

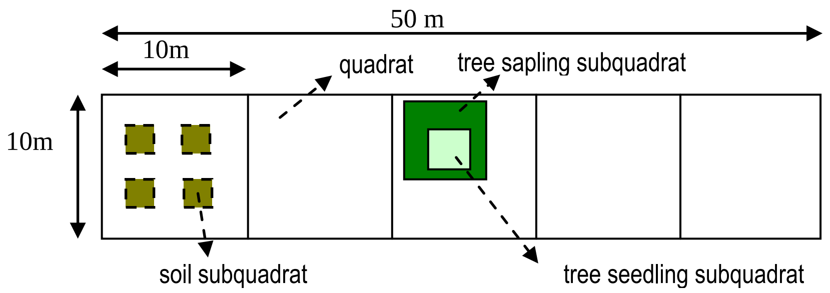


Figure 3.2. Design of sample plot for rattans, trees and soils

The various types of measurements are described in the following sections.

3.2.1.2 Rattan clumps and canes

Rattan measurements are divided into three levels: 1) for plants with cane(s); 2) for plants without a cane and > 1.5 m height; and 3) for rattan seedling < 1.5 m height. The data recorded for each level are:

1. for plants with cane(s): abundance, whether cane is harvestable or not, species name, estimate of cane length, evidence of previous harvesting, time elapsed since last harvesting
2. for plants without cane and > 1.5 m height: abundance, species name, evidence of previous harvesting
3. for rattan seedling < 1.5 m: abundance – since it is difficult to identify rattan names at the seedling stage.

The data collection scheme is shown in Figure 3.3.

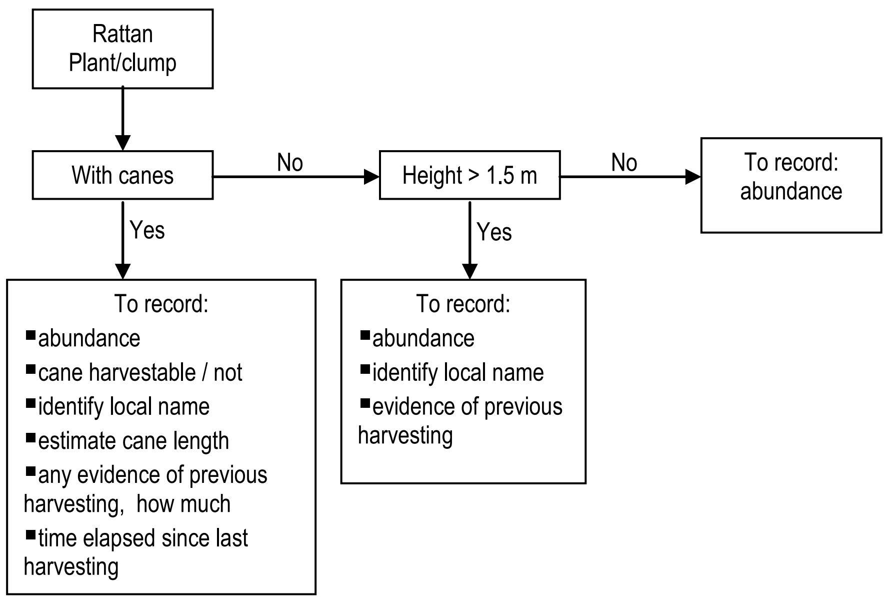


Figure 3.3. Data collection scheme for rattan plants/clumps and canes

Rattan abundance refers to the number of plants for solitary rattan and number of clumps for clustering rattan recorded in each quadrat. It is difficult to differentiate individual plants from the vegetative regeneration in a clump. One way of determining a distinct individual plant can be by observing the cane length, previous harvest and the number of canes (Siebert, 2005). In the clustering rattan, the multiple stems in a clump closely resemble the characteristics of one plant (Sunderland, pers. comm). For the abundance of clustering rattan, this study recorded each clump as an individual.

Vernacular names were given by the guides. These names were then matched to rattan species identified by a botanist working in the same field (Powling, 2009).

Direct measurement of cane length is very difficult to conduct in the field, because rattan canes are mostly climbers and very often wind around tree branches near the plants/clumps. Therefore, harvestability of the canes as well as a length estimate was conducted by the local guides who are/had been active rattan collectors and are conversant with estimating the length of climbing canes. Evidence of previous harvest and time elapsed since the last harvest were recorded by observing left-over cane stumps which remain for up to 3-4 years after harvesting.

3.2.1.3 Environmental and soil variables

Geographical locations were obtained from GPS measurements using a Garmin GPS 76s and altitudes were obtained from a 1:50,000 topographic map. With elevations of 0 m up to 700 m asl in Lambusango, attempts were made to observe if there are variations in vegetation structure at different altitudes.

Direct measurement of PAR is expensive, but indirect measurement from a hemispherical photograph can be used as the two are highly correlated (Whitmore *et al.*, 1993). Canopy gap measured using a canopy scope following Brown *et al.* (2000) was taken as a surrogate to estimate canopy cover or tree crown cover. This method is simpler and cheaper but shown to have high correlation with hemispherical photographs (Brown *et al.*, 2000).

Soil samples were taken in the sample plots from approximately 10-15 cm depth at 4 systematic points in the first and fifth quadrats of the plots (Figure 3.2). Soil samples were aired in the shade for between a few days to a couple of weeks before being sent to the laboratory for analysis. Plot slope angle was measured using a clinometer, while slope angles for broader landscape description were derived from the 1:50,000 topographic map.

3.2.1.4 Tree and understorey vegetation measurements

Tree and vegetation structure were measured in the field (see Figure 3.2). All trees in the quadrat with > 5cm dbh were sampled as was already described in section 2.2.4.2. Subquadrats of 5m*5m were used for inventorying saplings i.e. with <5cm dbh and > 1.5 m height, and only the dbh was recorded. For tree seedlings (<1.5 m height), subquadrats of 2m*2m were created within the sapling subquadrat and the number of tree seedlings was counted. The tallest tree in each quadrat was estimated to a 5 m category, e.g. 20-25 m height.

The cover of understorey vegetation, consisting of all vegetation including shrubs and tree saplings having heights of < 20 m, was recorded. Understorey vegetation was assessed in 3 height layers: 0-1 m, 1-5 m and 6-20 m, and cover of each layer was assessed using the Braun-Blanquet (BB) classification cover categories of <5%, 5-25%, 25-50%, 50-75%, >75% (Willis, 1973). Litter cover and top crown cover (tree heights >20m) were also recorded using BB classification. For analysis of the cover values, midpoint percentage values of the BB classes were used.

3.2.2 Analyses

3.2.2.1 Rattan species categorised

After being identified to species level, rattan species were categorised based on two factors:

- Based on the abundance: Each rattan species was categorised as 'common' or 'uncommon'. Common species are those present in at least 5 plots and/or having abundance of > 1% of the total sample.
- Based on commercial value: Each rattan species was grouped as 'commercial' or 'non-commercial'. The grouping was based on information from local guides and rattan harvesters (see Chapter Four).

Because abundance of common species is highly varied, for species present in all plots, abundance was calculated and analysed further, while for low abundance species not growing in all plots, presence/absence values were used.

3.2.2.2 Rattan species composition

Biological diversity is a term commonly applied to the "variety and abundance of species in a unit of study" (Magurran, 2004). Species richness is the most widely applied measure of biological or ecological diversity in a particular assemblage (Gaston and Spicer, 1998), but Magurran (2004) states that both species richness and species heterogeneity are used as diversity measures. Richness is defined as the number of species of a given taxon in a chosen assemblage; heterogeneity refers to the combination of richness and evenness components of diversity (Magurran, 2004). Magurran (2004) divides species richness into two measures: 'numerical species richness' which is more relevant for wildlife taxa and 'species density' which is the number of species per area unit and more relevant for botanical taxa. Furthermore, Magurran (2004) presents parametric and non-parametric approaches to calculating biological diversity. The parametric approach assumes that the species abundance distribution fits a mathematical series such as log, log normal or geometric series (Magurran, 2004). Non-parametric estimators benefit from not assuming any distribution, and include the Chao estimator to estimate richness and the Simpson index and Shannon diversity index to estimate heterogeneity (see Magurran, 2004; Kindt and Coe, 2005).

In this study, the measures to estimate species richness and diversity are: number of tree species, the Fisher's α index and the Simpson index, and were applied only to the common species found. The calculation of diversity indices in this study utilised 'Species Richness and Diversity' software by Pisces Conservation.

Fisher's α index assumes that species abundance follows a log series distribution (Magurran, 2004):

$$\alpha\, x\,,\ \frac{\alpha\, x^2}{2}\,,\frac{\alpha\, x^3}{3}\,, \ldots.. \ \frac{\alpha\, x^n}{n}$$

where $\alpha\, x$ is the number of species predicted to have one individual, $\alpha x^2/2$ is the number predicted to have two individuals, and so on.

The index α is calculated as shown in Equation 3.1:

$$\alpha = \frac{N\,(1-x)}{x} \qquad (3.1)$$

where x is obtained from:

$$\frac{S}{N} = [(1-x)/x] \cdot [-ln(1-x)] \qquad (3.2)$$

where S is the total number of species, N is the total number of individuals; x is almost always $0.9< x < 1$, and is never > 1.

This approach is usually followed by comparing the predicted values obtained from the calculations with the observed values from the actual sample data using a test of goodness of fit to check if the samples do follow a log series distribution. In this study, the Fisher's α index was taken only as a species diversity measure and no attempts were made to compare the resulting indices with the observed values from the samples. Magurran (2004) stated that this index is a robust measure even when the data do not follow log series distribution.

Simpson index calculates the probability that two individuals drawn at random in an infinitely large community are from the same species (Magurran, 2004; Equation 3.3).

$$C = \sum_i^{S_{obs}} p_i^2 \qquad (3.3)$$

where S_{obs} = number of observations, and p_i^2 is obtained from Equation 3.4.

$$p_i^2 = \frac{N_i\,(N_i - 1)}{N_T\,(N_T - 1)} \qquad (3.4)$$

where N_i is the number of individuals of the i th species and N_T is the total number of individuals in the sample.

The higher C is, the lower the diversity. Therefore to emphasise the diversity, the Simpson Index is commonly presented as the reciprocal (Equation 3.5).

$$D = \frac{1}{C} \tag{3.5}$$

A higher value for D indicates higher species diversity. The Simpson index is considered biased towards the dominant species in the sample (Magurran, 2004; Stocker *et al.*, 1985). The Simpson index is used in this study to obtain an indication of species dominance, and with the default index (D) produced by the software being used in this study, the interpretation needs to be adjusted, i.e. higher dominance is shown by a lower value of the index.

A ***Rank/abundance plot*** or Whittaker plot was also employed to observe the overall species dominance versus evenness in each site. This plot is obtained by plotting the rank of abundance in sequence from the most to the least abundant along the x axis and with the $\log_{10}$ of abundance presented on the y axis. A steeper curve indicates higher dominance while a shallower curve shows higher evenness in the species abundance (Magurran, 2004).

3.2.2.3 Rattan standing stock

Rattan standing stock refers to both the plant/clump and the harvestable canes. The measures include:

- presence-absence (P/A) of mature plants/clumps per species for common species
- abundance of plants/clumps per species for common species

Abundance of clumps for clustering rattan is considered equivalent to the abundance of plants for solitary rattan. When referring to both clustering and solitary species, for simplicity, the term “plant” is used. For cane standing stock analyses, the emphasis is on the rattan species commonly harvested by the villagers and having commercial value. Therefore cane abundance only considered ‘commercial’ species.

Cane length was recorded in two manners, total length and harvestable length, depending on the guide(s) confidence in their estimates. However, for standing stock assessment it was harvestable length that was taken into account. The minimum harvestable length (i.e. the minimum length of cane that can be sold) is 5-7 m, and for some rattan species, the lowest 2-3 m part of the cane is not harvestable.

3.2.2.4 Variables and cases – definition

The main analysis was conducted on the dataset collected from the 44 sample plots.

To investigate the relationships between rattan species composition and environmental variables, a series of predicting and response variables were established. Response variables in this study can be broadly grouped into *rattan species diversity and abundance*. The variables assessed are: presence-absence (P/A) of rattan plants per species, abundance of rattan plants per species, and abundance of total mature rattan for common species. Due to harvesting activities which are uncontrolled in these analyses, abundance of rattan canes was excluded from the statistical analyses.

The predictors in this study consist of environmental variables and soil properties. *Environmental variables* consist of altitude, slope angle and understorey light regime, which were all taken as measured values from the plot measurements. *Soil properties* consist of texture, pH, fraction of carbon (C), fraction of nitrogen (N), Cation Exchange Capacity (CEC), Base Saturation (BS) and soil macro nutrients (phosphate (P_2O_5), potassium (K), calcium (Ca), magnesium (Mg)), which are considered important indicators of forest soil quality (Schoenholtz *et al.*, 2000). Soil chemical properties were extracted at the Soil Laboratory at the Center for Soil and Agroclimatic Research, Bogor.

Rattan and trees share their growing habitat in the forest and it has been identified in previous studies that rattans variedly depend on trees for their shade and as climbing support for the canes (section 3.1.1). To observe the association between rattan abundance and tree and vegetation structure, two types of measure were used: *tree structure* consisting of tree density per ha, average tree dbh, maximum tree dbh, tree above ground biomass (AGB), average height of tallest trees, maximum height of tallest trees, range of heights of tallest trees and tree crown cover; and *understorey vegetation* consisting of ground vegetation cover (< 1m height), cover of second level of vegetation (1-5 m) and cover of third level of vegetation (6-20m); Litter cover was also included as an understorey layer.

3.2.2.5 Effects of environmental and vegetation variables on rattan abundance and composition

F-tests in ANOVA were used to identify significant differences in abundance of total mature rattan plants (plants per ha) and abundance of rattan canes among the six sites. The non-parametric Kruskal-Wallis test was used to identify significant differences in Fisher's α and Simpson indices.

For ANOVA, all the raw data were checked for normality through their skewness and kurtosis values, and by comparing the data to a normal curve. Using the skewness and kurtosis threshold values of +3 and -3 (Marcoulides and Hershberger, 1997; DSS, 2008), data outside the range were considered not normally distributed and were transformed to achieve normality. There is no one best way to correct for normality (Marcoulides and Hershberger, 1997). Therefore different methods were tried, mainly square root and $\log_{10}$ transformations, and the transformed values which are closest to normality were further used for analyses. Homogeneity of variance was checked prior to multiple comparison tests and post-hoc multiple comparison tests were conducted applying Bonferroni or Dunnett-T3 methods (Garson, 2009). For the non-parametric tests, the Mann-Whitney U test was applied to identify pairwise significant differences.

Ordination is an approach which is commonly applied to find the effects of environmental factors on biological communities. Ordination is defined as *'the ordering of a set of data points with respect to one or more axes'.* Alternatively, the displaying of a swarm of data points in a two or three-dimensional coordinate frame so as to make the relationships among the points in many-dimensional space visible on inspection. (Pielou, 1984, cited in Palmer, 2009). Two types of gradient analyses within the ordination methods are 'indirect' and 'direct', in which the differences lie in the types of variables analysed. 'Indirect gradient analysis' utilises only the species data, while 'direct gradient analysis' utilises environmental data in addition to the species data (Ter Braak, 1994; Palmer, 2009). For direct methods, due to the multiple gradients, reduction of dimensions is commonly applied due to the multiple gradients of the environmental data, and hence the term 'constrained ordination' (Ter Braak, 1994; Palmer, 2009).

Canonical Correspondence Analysis is one type of constrained ordination which originates from Correspondence Analyses (CA). It uses a reciprocal averaging algorithm in combination with multiple regressions applied to the sample scores of the environmental (predicting) variables (Watts, 2006). It is a method originally developed to analyse and visualise the relationships between many species and many environmental variables (Ter Braak, 1987).

In this study, CCA was applied to assess the effects of soil and environmental variables on rattan species composition and diversity. CCA was also applied to investigate the association between tree and vegetation structure and rattan abundance and presence, with the focus given to commercial rattan species. Raw data were applied without transformation to a normal distribution, because CCA uses permutations for randomization (Ter Braak and Smilauer, 2002). CANOCO software was utilised for the execution of CCA and 499 Monte Carlo permutation tests were conducted to reach appropriate levels of significance. An indication of how well explanatory variables explain the variation of response variables can be taken from the ratio of all canonical eigenvalues from all eigen values (Ter Braak and Smilauer, 2002).

Further observations using scatter plots and t-tests were conducted with the variables showing strong correlations (> 0.5 or < -0.5).

A separate assessment was conducted to observe the relationship between rattan seedling abundance and light regime. Despite the wide range of light tolerance by rattan plants, Dransfield and Manokaran (1994) noted the shade preference of rattan seedlings for some species (see section 3.1.1). To try to find evidence of such a relationship between the early stage of rattan regeneration and understorey light regime, simple regression and visualisation with scatter plots were used.

3.3 Results

3.3.1 Rattan species composition and abundance

The inventory and measurements of rattan and environmental factors were successfully conducted in 44 plots across the six sites. 18 rattan local names were recorded in the field and of these 18 names, 12 rattan names were identified into 11 species, 2 names into 2 genera of *Calamus sp* (Powling, 2009) and 4 names were unidentified and thus were also recorded as *Calamus sp* (see Table 3.1). A complete list, pictures and brief descriptions of each rattan species are presented in Appendix 4.

Of the 17 species on the list, 14 species are clustering rattans and only three species are categorised as solitary rattan (Table 3.1). The number of stems for a mature clustering rattan is varied. Common clustering species with large and medium diameter canes were observed to have between 2 to 6 stems per clump, while the small diameter species *Kabe* (*Calamus sp*.) has a large number of canes, up to 20 canes per clump (field observation).

Table 3.1. Rattan local names, species and other characteristics

Name code	Local name	Species*	Clustering/ solitary	Common sp	Commercial sp**
1	*Mombi*	*Calamus zollingeri* Becc.	Clustering	yes	yes
2	*Batang asli*	*Calamus zollingeri* Becc.	Clustering	yes	yes
3	*Lambang*	*Calamus ornatus var. ornatus Blume*	Clustering	yes	yes
4	*Kabe*	*Calamus sp.*	Clustering	yes	yes
5	*Umbul*	*Calamus symphysipus* Mart.	Solitary	yes	yes
6	*Daramasi*	*Calamus leiocaulis* Becc. ex K.Heyne	Clustering	yes	no
7	*Hoa*	*Calamus mindorensis* Becc.	Solitary	yes	yes
8	*Tohiti*	*Calamus sp. Nov.2*** **	Solitary	yes	yes
9	*Kai Sisau*	*Calamus minahassae* Warb. ex Becc.	Clustering	yes	no
10	*Noko*	*Daemonorops robusta* Warb. ex Becc.	Clustering	yes	no
11	*Bulurusa*	*Calamus sp.1**** *	Clustering	yes	no
12	*Torumpu*	*Calamus koordersianus* Becc.	Clustering	yes	yes#
13	*Mombi* ***	*Calamus sp.2**** *	Clustering	no	no
14	*Ngasa*	*Calamus pedicellatus* Becc. ex K.Heyne	Clustering	no	no
15	*Daramasi* ***	*Calamus sp.3**** *	Clustering	no	no
16	*Lakumpa*	*Calamus suaveolens* W.J.Baker & J.Dransf.	Clustering	no	no
17	*Pisi*	*Calamus leptostachys* Becc. ex K.Heyne	Clustering	no	no
18	*Batu*	*Calamus sp. 4*	Clustering	no	no

* *Based on identification in Powling, 2009*
** *Based on the names given by collectors in the interview (see chapters four and six)*
*** *Similar names were given by the local guide for plants that look to be different species*
**** *Unidentified by Powling, 2009, temporarily identified as Calamus spp.*
\# *Only identified as commercial by a few harvesters and regarded as the lowest quality of commercial rattan canes*

In the market, rattan canes in Lambusango are generally categorised into three types based on the diameter classes, and the three major commercial species are: *Calamus zollingeri* (known locally as *Batang* and *Mombi*, 25-35 mm cane diameter), *Calamus ornatus* (*Lambang*, ± 20 mm cane diameter) and *Calamus sp*. (*Kabe*, 7 mm cane diamater). Other species having similar characteristics and diameter are also harvested and sold together with the major species. The other large-diameter species is *Calamus mindorensis* Becc. (*Hoa*), medium diameter species are *Calamus symphysipus* (*Umbul*) and *Calamus sp. Nov 2* (*Tohiti*). *Torumpu* (*Calamus koordersianus* Becc.) is also considered a commercial species, although it was named as commercial by only a few harvesters. *Torumpu* was found only in one site (Bala) and was considered as the lowest quality medium-diameter commercial species.

A total of 2,104 rattan plants/clumps were inventoried in the survey and six to eight species were found in each site. *Calamus zollingeri* was the most abundant (35% of total abundance) and *Calamus ornatus* was the second most abundant (34%). From the rattan abundance and presence data, 11 species can be considered as common species (Table 3.1, and see explanation in section 3.2.2.1). The species considered uncommon and excluded from further analyses are *Calamus suaveolens* W.J.Baker & J.Dransf., *Calamus leptostachys* Becc. ex K.Heyne, *Calamus pedicellatus* Becc. ex K.Heyne, and 3 unidentified species (*Calamus sp. 2, Calamus sp. 3* and *Calamus sp. 4*).

3.3.2 Rattan characteristics across sites

Seventeen rattan species in Lambusango forest have been identified (Powling, 2009), with a few other rattan local names not yet properly identified. Less than half of the species are commercially valuable. Only commercial species are harvested, fulfilling the requirements set by buyers. The density of rattan plants and canes is presented in Table 3.2.

Table 3.2. Abundance of rattan plants and canes

Site	Number of plants ha^{-1}	Number of canes ha^{-1}
Anoa	806	374
Bala	1,293	863
Lapago	564	226
Lasolo	408	1,295
Wabalamba	1,085	564
Wahalaka	1,196	518

3.3.2.1 Comparison of rattan plant abundance

Across the six sites, the highest abundance of mature rattan plants is found in Bala (1,293 plants ha^{-1}), followed by Wahalaka (1,196 plants ha^{-1}) and the lowest is Lasolo (408 plants ha^{-1}). The major commercial species growing in Lambusango are *C. zollingeri* in Wahalaka, Anoa and Lapago, and *C. ornatus* in Bala, while in Wabalamba and Lasolo the dominance is shared by *C. zollingeri*, *C. ornatus* and *Calamus sp*. Figure 3.4 shows a comparison of species abundance among the sites.

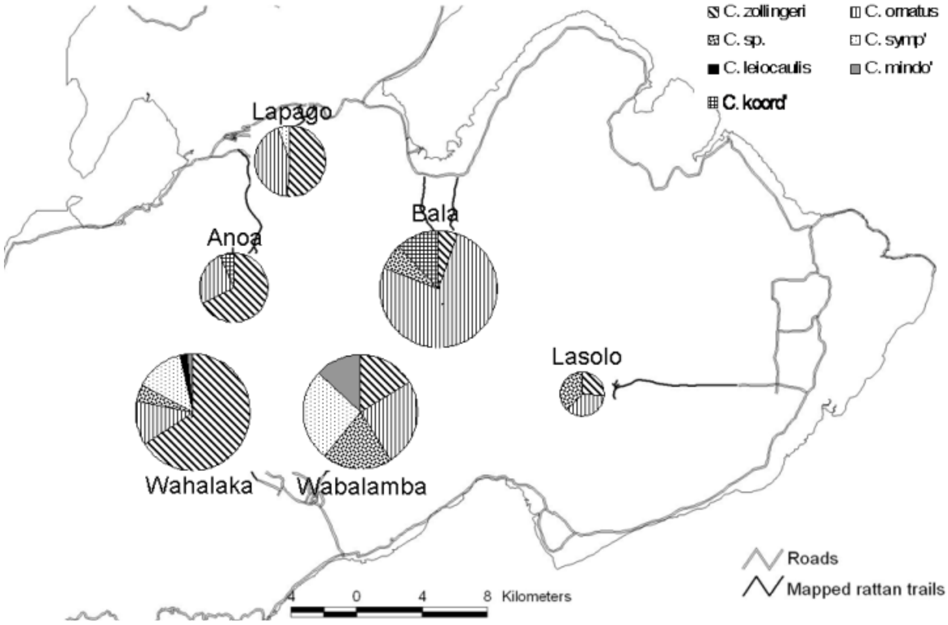


Figure 3.4. Rattan plant abundance of common species for each site (circle size represents approximate total abundance per hectare; C. koord = *C. koordersianus*, C. symp' = *C. symphysipus*, C. mindo = *C. mindorensis*)

The rank-abundance plot (Figure 3.5) shows that there are two types of site. First, there are sites (Wahalaka, Bala and Anoa) with one dominant species at rank #1 followed by a steep slope to species rank #2. In these sites, the most dominant rattan species are *Calamus zollingeri* for Wahalaka and Anoa, and *Calamus ornatus* for Bala. The second pattern has similar abundances for the first few dominant rattan species, followed by slightly steeper slopes for the less abundant species. This pattern occurs in Wabalamba and Lasolo where similar abundances occur for the first four major species of *Calamus symphysipus* Mart., *Calamus ornatus*, *Calamus sp*. and *Calamus zollingeri* in Wabalamba, and the three highest abundances of *Calamus sp*., *Calamus ornatus* and *Calamus zollingeri* in Lasolo. The rank abundance plot indicates that Wabalamba has the greatest evenness of species composition, followed by Lasolo, then Lapago.

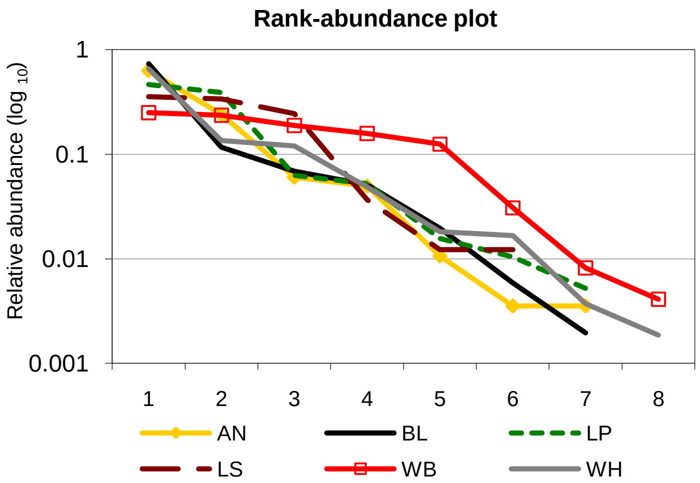


Figure 3.5. Rank-abundance plot of rattan species in six sites

3.3.2.2 Species composition and diversity

For the plot level indices, the Kruskal-Wallis test shows that Fisher's α and Simpson indices are significantly different among the sites at $p=0.02$ and $p=0.006$ respectively. Fisher's α index is significantly different only between Bala and Wabalamba, and for Simpson index, the significant differences occur between Bala and Wabalamba and Bala and Lasolo. Figure 3.6 shows the overall indices for each of the the six sites.

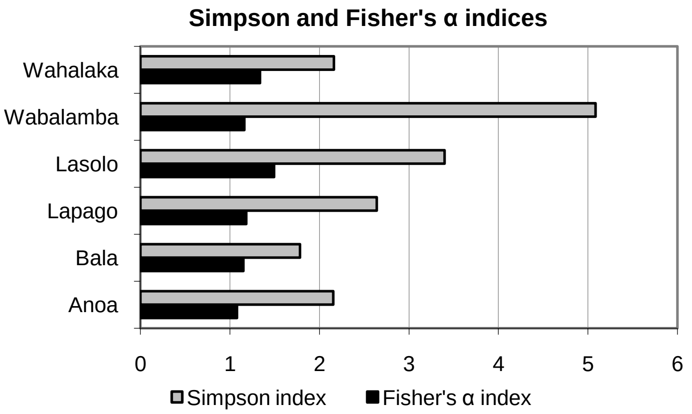


Figure 3.6. Simpson and Fisher's α indices of rattan species

3.3.2.3 Comparison of rattan cane abundance

Rattan canes show different patterns of abundance to the plants. Rattan canes of four species were found in the six sites. i.e. *Calamus zollingeri*, *Calamus ornatus*, *Calamus sp*. and *Calamus symphysipus* Mart. The highest total density of rattan canes occurs in Lasolo (1,295 canes per ha), and the lowest is in Lapago (226 canes per ha). Species with the highest cane abundance are *Calamus sp*. in Lasolo, Wabalamba and Wahalaka and *C. ornatus* in Anoa, Bala and Lapago (Figure 3.7).

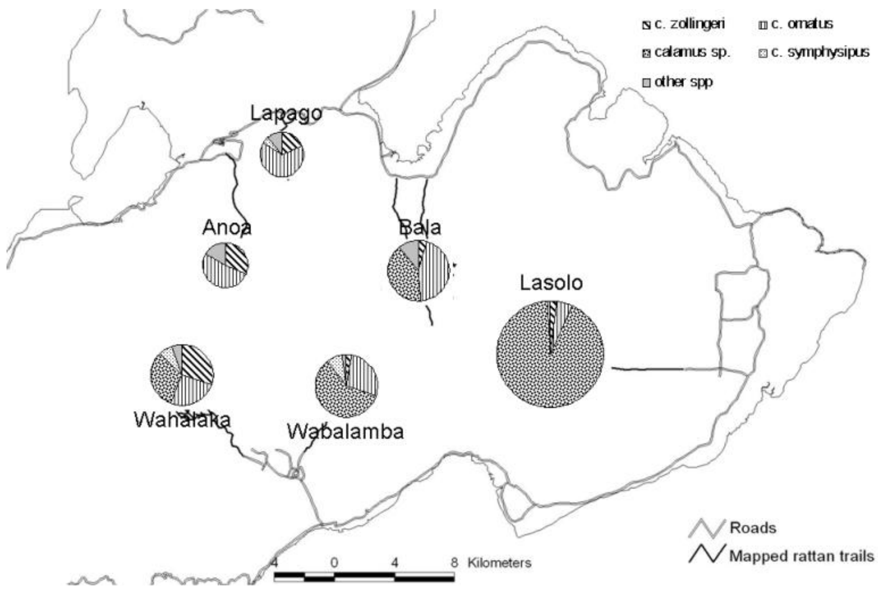


Figure 3.7. Cane abundance of commercial species for each site (circle size represents approximate total abundance per hectare)

3.3.2.4 Rattan seedling abundance

Mean abundance of seedlings is highest in Wahalaka (14,680 per ha) and lowest in Anoa (2,394 per ha), and the variations can be seen in the boxplot in Figure 3.8.

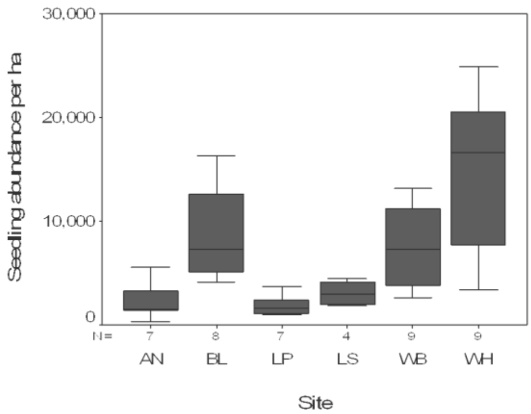


Figure 3.8. Rattan seedling abundance for each site

3.3.3 Environmental factors and soil properties across sites

The six sites in this study are located at various altitudes, from below 100 m asl (Lasolo) up to above 500 m asl (Anoa). The general altitude characteristics can be seen in Figure 3.1 and the variation across plots per site are shown in Figure 3.9(a). Lasolo is located in the lowest altitude range of 0-200m asl, Wabalamba at 100-200 m asl, Wahalaka and Lapago at 200-400 m asl, Bala at 250-500 m asl and Anoa at the highest altitude of 400 m up to 600 m asl. The largest slope variations across plots occur in Bala, Lapago and Lasolo. The plots with the flattest slopes are in Wabalamba (Figure 3.9 (b)). Understorey light varies greatly in Wabalamba, Anoa and Lapago, ranging from around 0.1 to above 0.5, while in Lasolo it is homogenously low at around 0.2.

From the 44 samples, soils range from strongly acid (ph 4.8) to weakly alkaline (ph 7.5) (Young, 1976), with the most acid soils found in plots in Bala. The textures are mostly clay with silty clay loam in Anoa, clay loam in Bala and Wabalamba, and silty clay in Wahalaka, while in Lapago the soil textures are more varied consisting of the three combinations (clay, silt and loam).

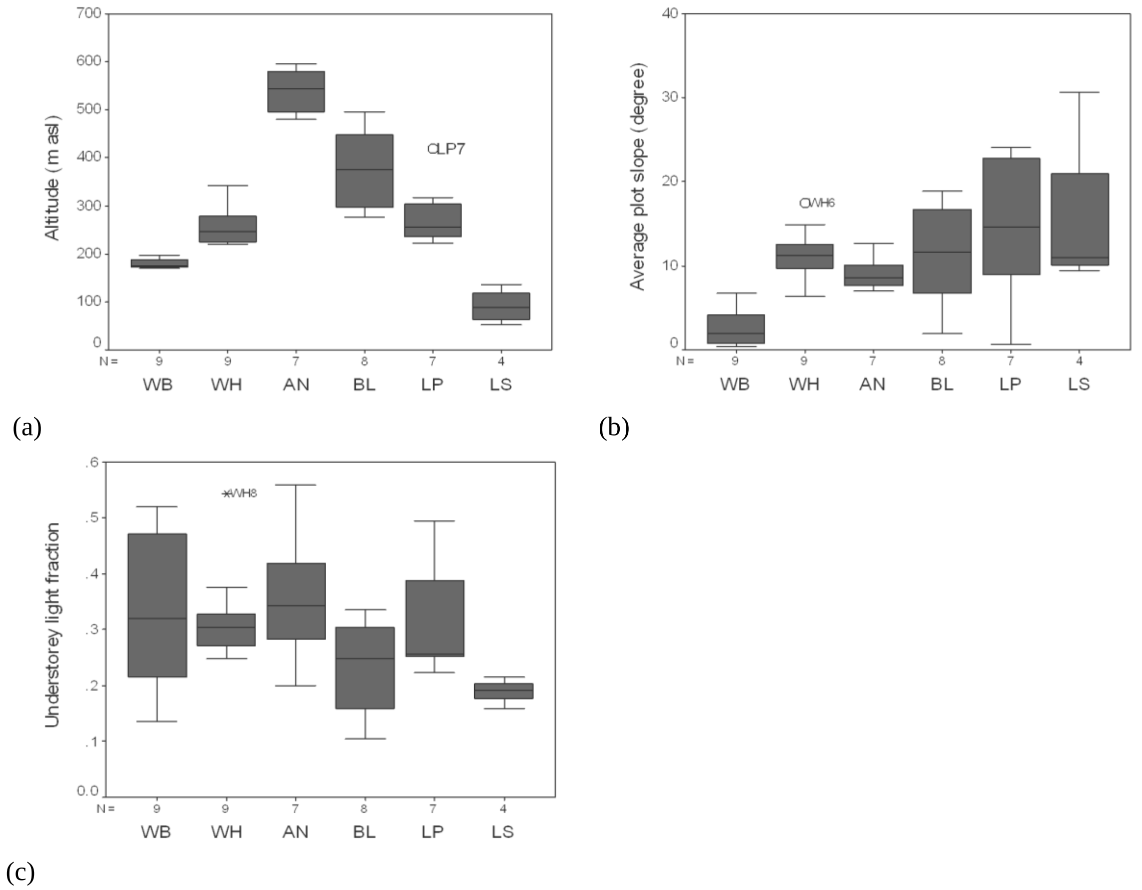


Figure 3.9. (a) altitude variations across sample plots; (b) slope variation across sample plots; (c) understorey light across sample plots

An F-test in one-way ANOVA shows significant differences in pH, Ca, Mg, K and P_2O_5 (at $p< 0.05$). The Bonferroni and Dunnett-T3 tests show that Bala generally has significantly lower pH, Ca and P_2O_5 at $p< 0.05$ compared to some other sites. The soils in Bala are more acidic than the soils in the other sites. The tests on other properties i.e. texture group, C fraction, N fraction and CEC do not show significant differences among the six sites. Table 3.3 shows the significant F-test results of soil variables across sites.

Table 3.3. F-test results of soil variables across sites

Variables	F	*p*-value *
pH	4.6556	0.0021
Ca (sqrt)	4.0875	0.0046
Mg (log10)	4.1555	0.0041
K (log10)	2.9293	0.0248
P205 (log10)	10.8273	0.0000

** Significant at p<0.05*

3.3.4 Environmental and soil chemical effects on rattan species

3.3.4.1 Effects of soil and environmental factors on species abundance

CCA results show that the first two axes explain cumulatively 46.2 % of the total variance while the first axis alone explains 28.3 % (Table 3.4). The biplot in Figure 3.10 shows the weighted correlations of the predictors as arrows. Dominant variables on the first axis are pH and base saturation (BS) with weighted correlations of -0.69 and -0.58 respectively. Dominant variables on the second axis are altitude and P_2O_5 with weighted correlations of 0.787 and -0.551 respectively (Table 3.5).

Table 3.4. CCA summary output for common rattan species and soil-environmental factors

Axes	1	2	3	4	Total inertia
Eigenvalues:	0.329	0.208	0.06	0.016	1.161
Species-environment correlations:	0.779	0.81	0.609	0.497	
Cumulative percentage variance					
of species data:	28.3	46.2	51.4	52.7	
of species-environment relation:	52.6	85.8	95.4	98	
Sum of all eigenvalues					1.161
Sum of all canonical eigenvalues					0.625

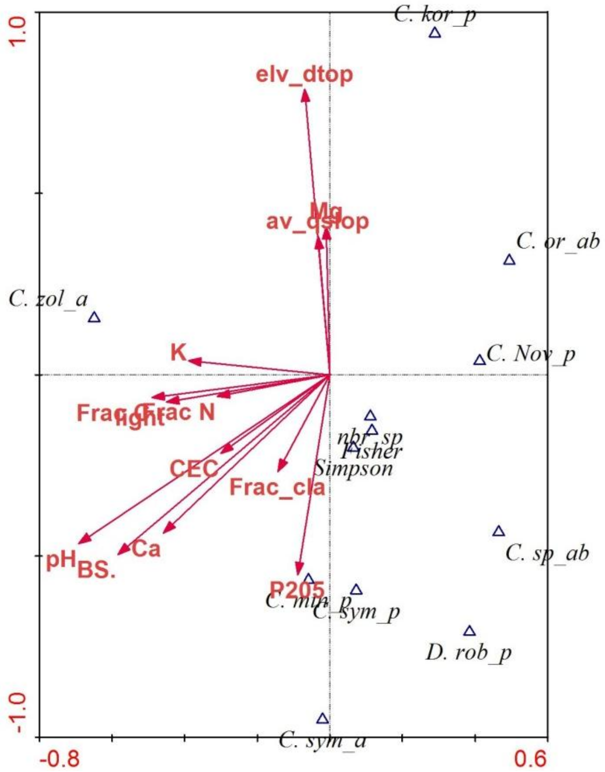


Figure 3.10. Biplot of CCA results for rattan species and soil and environmental factors (Remarks: *C. kor = C. koordersianus, C. or = C. ornatus, C. min = C. mindorensis, C. Nov = Calamus sp. Nov.2, C. sym = C. symphisipus, C. zol = C. zollingeri, D. rob = D. robusta; _a or _ab = abundance, _p* = presence; see Table 3.5 for factor abbreviations)

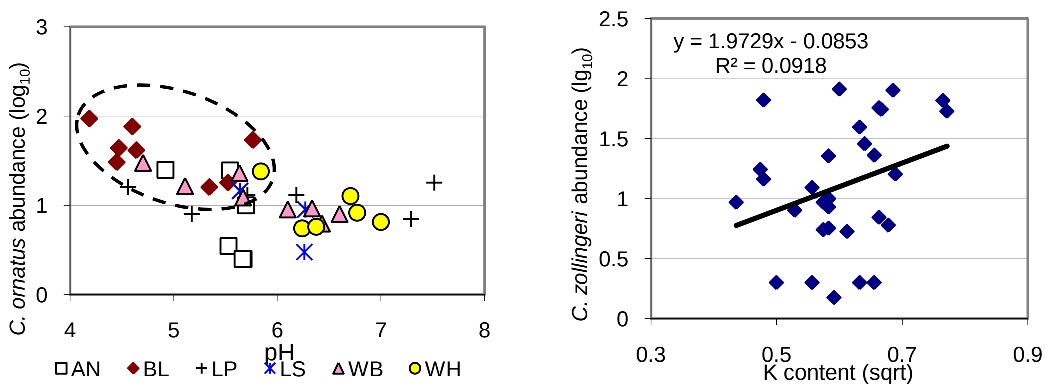
Response variables that score highly on the first axis are *C. zollingeri* abundance, *C. ornatus* abundance and *Calamus sp*. abundance. Response variables that score highly on the second axis are *C. symphysipus* abundance, *D. robusta* presence and *C. koordersianus* presence. Among the rattan measures tested, variation in *C. zollingeri* abundance can be explained by variation in potassium and *C. mindorensis* presence by variation in phosphorus. *C. ornatus* abundance is shown to be negatively related to pH and *C. symphisipus* presence to altitude. The ratio of all canonical eigenvalues from all eigen values, indicating how much variation in rattan species can be explained by the variation in soil and topographical variables, is 0.625/1.161 = 0.538 or 53.8% (Table 3.4) and the relationship is significant at $p=0.006$.

Table 3.5. Weighted correlations of soil and environmental variables resulting from CCA

Variable	Abbreviation in biplot	Weighted correlations axis-1	Weighted correlations axis-2
Altitude (m)	elv_dtop	-0.0694	0.7871
Slope (degree)	av_qslop	-0.0321	0.3811
Light regime (fraction)	light	-0.4493	-0.0757
Clay Fraction	Frac_cla	-0.1431	-0.2668
pH	pH	-0.6917	-0.4657
Cation Exchange Capacity	CEC	-0.3005	-0.2164
Carbon (fraction)	Frac C	-0.4895	-0.0633
Nitrogen (fraction)	Frac N	-0.3098	-0.0593
Phosphorus (ppm)	P205	-0.0885	-0.551
Calcium (cmol (+) kg^{-1})	Ca	-0.4582	-0.4362
Magnesium (cmol (+) kg^{-1})	Mg	-0.0101	0.4075
Potassium (cmol (+) kg^{-1})	K	-0.3889	0.0382
Base saturation (%)	BS.	-0.5831	-0.4952

3.3.4.2 Individual relationship from CCA results

Upon obtaining the results of the contribution of soil properties and environmental variables to the variations in species shown in the CCA, individual relationships with high correlations were further examined. A scatter plot between pH and *C. ornatus* abundance was constructed (Figure 3.11(a)), after transforming *C. ornatus* into $\log_{10}$ to ensure normality, and the simple regression shows that there is a negative relationship between the variables with regression coefficient (R^2) of 0.328. A scatter plot between potassium (K) content and *C. zollingeri* abundance was also constructed (Figure 3.11(b)) after transforming the values into $\log_{10}$ for *C. zollingeri* and square-root for K. There is an indication of a positive relationship between the variables, although the relationship is very weak (R^2=0.092).



(a) (b)

Figure 3.11. (a) Scatterplot between pH and *C. ornatus* abundance (ellipse refers to Bala plots; see discussion, section 3.4.3); (b) Scatterplot between K content and *C. zollingeri* abundance

A t-test was used to determine significant differences in the mean altitude for plots with presence and absence of *C. symphysipus*. The result shows that altitude is significantly lower for the plots with *C. symphysipus* present (*p=0.006*). Square-root-transformed phosphorous (P) values were used to examine the differences in P content between the plots with *C. mindorensis* and those without. P content is significantly higher for the plots with *C. mindorensis* (*p=0.004*).

3.3.4.3 Rattan seedlings and light regime

The investigation of the effects of light regime on seedling abundance ignored three extreme values (outliers). The scatterplot of the results (Figure 3.12) shows there is no significant linear effect of light regime on the variation in seedling abundance (R^2= 0.032), but instead the distribution of seedling abundance shows a bell-shaped curve on the light gradient, and the highest range of seedling abundance is located within light fractions of 0.25-0.50.

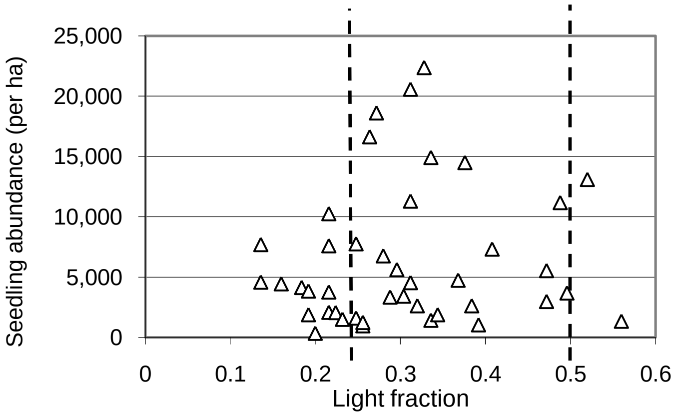


Figure 3.12. Distribution of seedling abundance in relation to understorey light fraction (vertical lines show 25% light regime intervals)

3.3.5 Association of rattan abundances with tree and vegetation

CCA results show that only a very small part of the variance is explained by the first two axes, i.e. 26.5%, while the first axis explains only 15.6% (Table 3.6). From the ordination biplot of CCA, indications of association between tree-vegetation measures and rattan measures are demonstrated by *C. symphysipus* and *C. mindorensis* presence on the gradient of tallest trees and understorey vegetation of 1-5m, *C. symphysipus* abundance on the gradient of ground cover of < 1 m, *C. koordersianus* on litter cover and seedling abundance on average dbh. *C. ornatus* abundance shows a negative correspondence with maximum dbh while *C. zollingeri* abundance is negatively related to understorey cover of 1-5 m. However, the tree and vegetation measures only explain a small amount of the variation in rattan species presence and abundance, i.e 0.086/0.236= 0.364 or 36% (see Table 3.6) significant at *p=0.02.*

Table 3.6. CCA summary output for common rattan species and tree and vegetation

Axes	1	2	3	4	Total inertia
Eigenvalues :	0.04	0.03	0	0.01	0.236
Species-environment correlations :	0.68	0.7	0.5	0.48	
Cumulative percentage variance					
of species data :	15.6	26.5	31	34.6	
of species-environment relation:	42.8	73	85	95.4	
Sum of all eigenvalues					0.236
Sum of all canonical eigenvalues					0.086

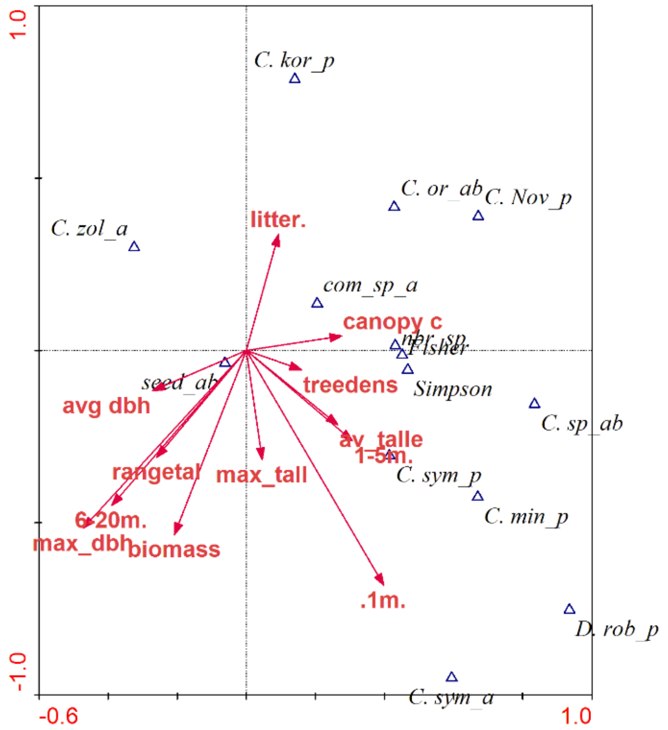


Figure 3.13. Biplot of CCA results for common rattan species and tree-vegetation measures (Remarks: *C. kor = C. koordersianus, C. or = C. ornatus, C. min = C. mindorensis, C. Nov = Calamus sp. Nov.2, C. sym = C. symphisipus, C. zol = C. zollingeri, D. rob = D. robusta; _a or _ab = abundance, _p =* presence; see Table 3.7 for factor abbreviations)

Table 3.7. Weighted correlations of tree and vegetation structure variables resulting from CCA

Variables	Abbreviation in biplot	Weighted correlations axis-1	Weighted correlations axis-2
Tree average dbh	avg dbh	-0.271	-0.1167
Tree maximum dbh	max_dbh	-0.4722	-0.5154
Tree density	treedens	0.1595	-0.0563
Tree canopy cover	canopy c	0.2754	0.0418
Tree AGB	biomass	-0.2084	-0.5341
Litter cover	litter.	0.0936	0.3364
Understorey cover, height < 1m	.1m.	0.3979	-0.6814
Understorey cover, height 1-5m	1-5m.	0.3065	-0.2617
Understorey cover, height 6-20 m	6-20m.	-0.3894	-0.449
Max. height of tallest trees	max_tall	0.0455	-0.317
Average height of tallest trees	av_talle	0.2645	-0.2158
Height range of tallest trees	rangetal	-0.2598	-0.3098

3.4 Discussion

3.4.1 Rattans in different parts of the forest

Most of the common rattan species found in Lambusango are clustering species with only three solitary species found, all three of which produce second class rattan canes. At the six forest sites, two species were found to be the most abundant: *C. zollingeri* and *C. ornatus*, both of which are first class in their diameter classes. Species dominance varies between the six sites. In Wahalaka, Anoa and Lapago, *C. zollingeri* dominates. In these sites, *C. zollingeri* has different local names, *Batang Asli* in Lapago and Anoa (the northern sites of Lambusango forest) and *Mombi* in Wahalaka. In Bala, *C. ornatus* is the dominant species. In Lasolo, *C. ornatus* and *Calamus sp*. are dominant. Wabalamba has the most even species composition with the four species *Calamus symphysipus* Mart., *Calamus ornatus*, *Calamus sp*. and *Calamus zollingeri* sharing similar levels of abundance. This diversity is shown quantitatively by a significantly higher Simpson index indicating the highest diversity and lowest dominance.

Across the six sites, rattan canes have different patterns of abundance and distribution compared to the plants. The highest abundance of canes occurs in Lasolo with *Calamus sp*. canes being the most abundant. *Calamus sp*. also has a high proportion of cane abundance in Wahalaka and Wabalamba, despite the low actual number. *Calamus sp*. is the major small-diameter cane rattan and a clump may produce up to 20-30 canes. Other clustering rattans only had up to 6 canes per clump, although harvesting of these species might have reduced the natural cane production potential.

Low abundance of *C. zollingeri*, the most commercially valuable rattan species, in various sites is most likely due to high rattan harvesting levels. As is discussed later in Chapter Four, Wahalaka and Wabalamba have high levels of rattan cane harvesting, and therefore *C. zollingeri* cane abundance in these sites may be reduced, as may also be the case in Bala. Harvesting solitary rattan canes is less sustainable than multi-stemmed species, which is reflected in the results of this study as there are almost no canes left of the solitary rattans (*C. symphysipus*, *C. mindorensis* and *Calamus sp. Nov.2*), although there are a number of young solitary rattan plants in some sites.

A high abundance of *Calamus sp*. canes was found. The cane of this species is not always demanded by rattan companies/buyers. The rattan market in the Lambusango area is dominated by large and medium diameter canes (*C. zollingeri* and *C. ornatus* classes) and only at specific periods are small diameter canes in demand. Based on local information, there is also a common understanding that harvesting *Calamus sp*. is banned by the forestry authority and harvesting this species could lead to imprisonment. At a smaller scale, in some villages, there is an indication of non-registered *Calamus sp*. cane harvesting for local production of basketry. These canes are usually sold in local markets or to supply local basket-making. The perception of a ban on *Calamus sp*. harvesting could be because this type of harvesting is usually not based on concession permits controlled by the forestry authority. Therefore, *Calamus sp*. canes could be highly abundant in many parts of Lambusango Forest due to the combined effects of abundant canes per clump, infrequent harvesting concessions and the rumours of punishment deterring harvesting for local sale.

3.4.2 Rattan distribution and the influence of environmental factors

The altitudes at which rattan have been found in this study range from 51 m to 596 m asl which is within the general range for abundant rattans to be found. Two commercial species found in this study, *C. zollingeri* and *C. symphysipus*, are known to grow at up to 1330 m asl (Siebert, 2005). However, results for *C. symphysipus* show a negative relationship with altitude, growing mostly at below 450 m asl, while higher altitudes show absence of this species. The significant results for presence or absence of solitary species such as *C. symphysipus* found in this study should be interpreted with caution. Harvesting single-stem or solitary rattan species inevitably means killing the plant, and therefore distribution of this species might be biased by the effect of harvesting. However, since altitudes above 500m asl are only found in the Anoa site for plots located at the far end of collection areas or even outside the harvesting destinations (see Chapter Four), this significant result probably indicates a genuine biological limit to the distribution. The potential influence of harvesting on the results is discussed further below.

Other environmental factors tested, i.e. slopes ranging from 0 to 30 degrees, and light regimes ranging from 10% up to 56%, do not significantly influence distribution of rattan species abundance. As stated by Dransfield and Manokaran (1994), rattan may tolerate open canopy as well as full shade. Siebert (1993) concluded that *C. zollingeri* plants prefer a light environment, but such evidence was not found in this study.

Regarding the effect of the light environment on rattan regeneration, there is no linear relationship between seedling abundance and light fraction. However, an indication of certain light-regime preference for rattan regeneration was shown by abundance variability being greatest within the 0.25-0.5 light fraction range, where regeneration can reach up to 1,100 seedling per plot, equivalent to 22,000 seedlings per ha. This indicates that a moderately shaded environment is preferable for seedling growth compared to the extremes of closed canopy ($\leq$ 0.2) or gap area ($\geq$ 0.5). This result indicates agreement with Dransfield and Manokaran (1994) on rattan seedling shade preference.

3.4.3 Effects of soil factors

Soil chemical properties do not show significant effects on the abundance of the common species observed in this study. There are indications that potassium content contributes to the abundance of *C. zollingeri* and phosphorus content to the presence of *C. mindorensis*. However, observing the relationship between *C. zollingeri* abundance and potassium content, although there was a positive trend, the relationship is very weak. The significantly higher phosphorous content associated with the presence of single-stem *C. mindorensis* once again has to be interpreted with caution because the absence of *C. mindorensis*, being a solitary rattan, might be the effect of the death of the plant upon harvesting the mature cane and not necessarily due to the soil phosphorous factor.

Soils in Bala were found to be significantly more acid compared to the other sites and it is only in Bala that *C. ornatus* dominates. Further, evidence showed that higher *C. ornatus* abundance occurs in low soil pH plots, with most of these low pH plots being in Bala. For soil pH above 5.5 the influence bottoms out at a stable minimum level of *C. ornatus* abundance.

3.4.4 Association with tree and vegetation structure

Causal relationships between rattan abundance and tree and other forest vegetation are possibly reciprocal. Rattan plants and canes are affected by tree and vegetation as their habitat and growing environment, in terms of among others light provision, humidity level and cane climbing support. In addition, survival and growth of rattan plants and canes might be affected by lower competition with understorey vegetation. Conversely, forest trees and vegetation may be affected by the presence and abundance of rattan plants and canes. Rattan may affect the survival and growth of shrub vegetation and tree seedlings, hence their lower cover. This latter relationship is likely to be intensified by the human disturbance of rattan cane harvesting. Due to these considerations, empirical testing to seek causal relationships between rattan and tree and vegetation structure are very likely influenced by biases and errors, and it was considered better to focus on the correspondence or association in habitat sharing.

There are indications of association between the presence and abundance of some rattan species with the density of understorey vegetation and heights of trees. However, evidence demonstrates only weak associations. For the major commercial rattan species there is an indication that higher abundance of *C. zollingeri* is associated with sparse cover of understorey layers and the higher *C. ornatus* abundance with smaller tree sizes. Results with regards to single-stem rattan species is possibly biased as discussed in section 3.4.3. and later in section 3.4.5. Overall, it can be concluded that there is not enough evidence in this study to state that variations of abundance and presence of common rattan species in Lambusango forest are associated with the variations of forest tree and vegetation structure.

3.4.5 Limitations to analyses

Rattan cane abundance was not tested against environmental and soil chemical variables due to the inaccuracy that would come from the effects of harvesting. Fewer than five sample plots in this study can be considered to be located in unharvested areas. Therefore, it is likely that measured rattan cane abundance is mostly the result of cane harvesting on top of natural factors affecting growth, number per plant and length. Observation of the effects of natural factors on rattan cane should be conducted in areas where there is no human disturbance or where such disturbance can be controlled. Such a trial can normally be conducted by establishing permanent plots, where harvesting of mature canes is not allowed or is controlled.

Similar problems apply to the plants of solitary rattan species (e.g. *C. symphysipus*, *C. mindorensis* and *Calamus sp. Nov*.2), because removal of the stem inevitably kills the plant. Therefore, absence or low abundance of these species might not be due to the variations in the measured natural factors, but instead, due to the death of the plants after harvesting. To conduct unbiased investigations on solitary rattans, similar approaches to the assessment of rattan cane should be applied.

Considering their reproduction limitations, solitary rattans which can only reproduce by flowering and fruiting and which can only regenerate through seeds, need more careful harvest management to ensure sustainability. Clustering rattans, on the other hand, have advantages from the management and harvesting sustainability perspectives (Siebert, 1993; Watanabe and Suzuki, 2008).

The results were also limited by the data collection and methods used in this study. Understorey light measurements might have differed if hemispherical photographs had been used instead of the canopy scope. Soil physical variables, which were not tested in this study, such as permeability and bulk density, might show different effects on the distribution of rattan species.

It should be noted that a multivariate method such as CCA does not infer causal relationships (McCune, 1997; Palmer, 2009). It merely shows correlations between the variables, and the causal relationship should be guided by a priori knowledge of possible species-environment relationships. Caution should be taken in applying multivariate ordination such as CCA when the number of variables is large. McCune (1997) and Palmer (2009) note that increasing the number of variables will result in increasing 'explained variance' similar to the increasing multiple R^2 in multiple regressions. As more variables are included, there is an increasing level of explanation by the combination of explanatory variables, although in reality this does not necessarily represent stronger relationships between the explanatory variable(s) and the response variable(s).

3.5 Summary and conclusion

This study aims to describe the distribution of common and commercial species of rattan across the Lambusango area represented by six study sites and to explain the differences in abundance and diversity by analysing potentially influential soil and environmental factors.

Seventeen rattan species had been identified in the Lambusango area (Powling, 2009) and across the six study sites, two dominant species were found: *C. zollingeri* and *C. ornatus*. Both are the most commercially valuable species in their diameter classes, *C. zollingeri* for the large diameter class and *C. ornatus* for the medium diameter class. The highest number of species occurs in Wahalaka, the site with the highest diversity (and lowest dominance) is Wabalamba and the site with highest species dominance is Bala (*C. ornatus* being the most dominant). However, diversity is not affected by the environmental and soil variables examined in this study.

The effects of soil and environmental factors on species abundance and diversity were investigated by applying canonical correspondence analysis (CCA), simple regressions and Student t-tests. Others have found many rattan species to be tolerant of a wide range of altitudes, slopes and light environments. In this study, *C. symphysipus* was absent at higher altitudes, while for the other species, the range of altitudes in Lambusango forest can be considered favourable for growth. Variations in slope and light regime do not show significant effects on rattan species abundance or diversity. Rattan seedling abundance was not found to be linearly correlated with light regime, in contrast to shade preference found in other research. However, there are indications that seedlings may be more abundant in moderately shaded environments compared to the extremes of closed or open canopies. No significant evidence was found of an association between variations in tree and vegetation structure and variations in rattan abundance and presence.

There is some evidence that chemical properties influence some rattan species. There is strong indication that *C. ornatus* is more abundant on soils with lower pH.

Rattan cane abundance was highest in Lasolo, dominated by *Calamus sp*., which may be explained by the lower commercial value of this species during the period of observation. The low abundance of *C. zollingeri*, the most commercially valuable species in the Lambusango area, especially in sites where rattan cane harvesting is high, is most likely due to the effects of harvesting.

Rattan cane abundance was not tested against soil and environmental factors because the results would be biased by the effects of cane harvesting. For further investigation of the effects of natural factors on rattan canes, sample sites should be established to remove the effects of cane harvesting, or cane harvesting should be controlled. Similar considerations apply to investigation of solitary or single-stem rattans due to the death of the plant when the cane, which is the mature stem of the plant, is harvested. Therefore, interpreting the significant effects of soils and environmental factors on solitary rattans in areas where harvesting takes place, as in this study, should consider the possible bias of harvesting effects.

Chapter 4. Accessibility factors and conservation forest designation affecting rattan cane harvesting

4.1 Introduction

With continuing rattan cane harvesting activities in Lambusango forest, ongoing studies aim to assess the level of extraction and its ecological sustainability. It is necessary to gain a better understanding of the harvesting activity, such as harvesting destinations in the forest, modes of transport, frequency of harvesting and factors such as accessibility in the forest.

4.1.1 Rattan harvesting and the accessibility factors

There has been little examination of the accessibility factors that could affect levels of forest product extraction. Siebert (2001) indicated that the extent of rattan cane extraction was limited by distance. A few studies of human activities in forests, such as deforestation and other NTFP extraction, have shown that such activities are affected by limiting physical factors such as accessibility (Kaimowitz and Anglesen, 1998; Shaanker *et al*., 2003). Considering the labour-intensive nature of rattan cane harvesting (Paumgarten, 2006), physical conditions such as forest accessibility are thus assumed to affect the quantity harvested.

Forest dwelling or other human activities widely take place in forests designated as protected conservation areas (Gunatilake *et al*., 1993; Masozera and Alavalapati, 2004; Siebert, 2004; Mbile *et al.*, 2005; Ndalangasi *et al*., 2007; Gubbi and MacMillan, 2008). Establishment of conservation forest in areas with ongoing livelihood activity might reduce the intensity and extent of the activity (Olupot *et al.*, 2009) although in other areas, due to the importance of the resource harvested, existence of protected area does not significantly affect levels of extraction (Ndalangasi *et al.*, 2007).

4.1.2 Participatory approaches

To develop understanding of the characteristics of small scale NTFP harvesting by local forest dwellers, direct involvement of the actors in data gathering is considered central. As recommended by Tripathi and Bhattarya (2004), to achieve sound management of natural resources, local participation should be incorporated. Participatory Mapping (PM), also widely known as Participatory Resource Mapping (PRM), is an approach to mapping resources which involves a community's participation and embeds their local knowledge. The approach usually involves discussion and map construction in which participants express their understanding of the resources familiar to them, be it as a sketch map on paper or map drawing on the ground using local materials (Kalibo and Medley, 2007). This approach was developed under the realm of Participatory Rural Appraisal (PRA) and first became popular in the early 1990s (Dovie, 2003; Chambers, 2006). Although the term PM emerged later after the long application of PRA, the ‘map drawing’ capability of local people has actually been used since the 1970s in the application of PRA in various studies (Chambers, 2006).

Incorporation of GIS technology into participatory mapping has become common, giving rise to the term Participatory GIS (PGIS). PGIS continues the principle of PRA (Rambaldi *et al*., 2006), using GIS technology in the context of the needs and capabilities of communities to capture local knowledge and combine it with more conventional spatial information (Abbot *et al*., 1998). PGIS brings local people’s knowledge into contemporary spatial data collection and management in GIS (Tripathi and Bhattarya, 2004). In the context of forest conservation, resource monitoring by the community not only allows them to improve understanding of the abundance or scarcity of the resources they harvest (Bawa *et al*., 2007), but also helps in locating and knowing the extent of the resources both by the researchers and the community themselves (Kalibo and Medley, 2007; Mbile *et al*., 2005).

Participatory approaches can be applied in combination with household surveys or structured interviews. This combination can be effective in obtaining better understanding of resource use by local people and the importance of forest products to their livelihood (Dovie, 2003; Malleson *et al*., 2008). The two approaches can be applied separately in the community (Malleson *et al*., 2008), or as a more integrated method, in which local people and key informants are asked to be involved in PRA exercises conducted at the household level (Dovie, 2003).

The objectives of this chapter are to assess rattan cane harvesting levels within and adjacent to the conservation areas and to assess whether harvesting levels are affected by accessibility factors and/or the conservation designation.

4.2 Methods

4.2.1 Rattan harvesting zone

In this study, a rattan harvesting zone (RHZ) is defined as the area and extent of a village’s rattan cane harvesting destinations in the forest. These zones do not have physical boundaries, and do not imply any official boundary for rattan cane harvesting, nor do they have management implications related to harvesting activities conducted in the forest. RHZ refers to an area delineated for the purpose of obtaining approximate harvesting extent for each village, for deriving topographic and accessibility variables for further analyses and for observing adjacency with designated forest zones. RHZs were generated using a combination of PM and GIS techniques.

4.2.1.1 Participatory mapping

Participatory mapping (PM) was undertaken with rattan harvesters at each village (see section 4.2.3 for sample design). The main objective was to produce a sketch map showing their harvesting destination areas and their perception of landscape and topographic components (see

Mbile *et al*. 2005; Duvail *et al*., 2006; Kalibo and Medley, 2007). The PM activity in this study did not attempt to delineate boundaries, although PM can be used for this purpose in some situations (Stockdale, 2005).

The objectives of the PM activity were explained to participants. Items to draw on the map were described, emphasising key features which were considered important. Participants were made aware of the objectives of the participatory mapping and those of the overall study. Sketch maps were drawn onto georeferenced printouts of Landsat satellite imagery (NASA, 2007).

4.2.1.2 GIS routines

Information from the sketch maps was transferred to GIS and was integrated with other layers of georeferenced information, namely stream network, elevation and land cover (Figure 4.1). The stream network and a digital elevation model were derived from 1:50,000 scale topographic maps (Bakosurtanal, 1989).

Interviews with rattan harvesters revealed that harvesting areas are likely to be bounded by mountain ridges which are difficult for collectors to cross while carrying rattan canes. Therefore, harvesting trips can be perceived as similar to the drainage flow in a river catchment system. Trips end at ridge tops and, with the bundle of canes to carry, the return trip takes the shortest and/or most accessible downward route to the main pathways or rivers heading back to the village. For that purpose, watershed delineation routines in ArcView were used initially to delineate mountain ridges bounding the river catchments (ESRI, 1999; Schäuble, 2004). To obtain the final RHZ, delineated catchment boundaries were adjusted using information on streams, distance and other landscape features recorded from the PM activity.

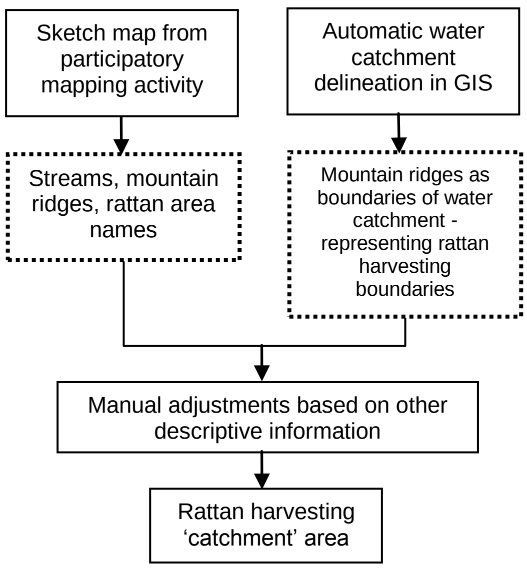


Figure 4.1. Flow diagram for integrating sketch map into GIS

RHZs were superimposed on a designated forest zone map layer and three categories of RHZ were defined: i) RHZ completely within Conservation Forest, ii) RHZ partially within Conservation Forest, and iii) RHZ in Production Forest.

4.2.2 Accessibility parameters

For each RHZ, accessibility measures were derived from the digital elevation model. Distance calculations were based on the planimetric distance adjusted by slope angles to give true field distance. Due to the absence of walking routes/pathways, the incorporation of slope angle into the shortest-distance measure is considered sufficient to represent field distance, although this does not take into consideration reduced accessibility due to factors such as impenetrable vegetation or river crossings.

Six accessibility variables were produced:

1. Distance to harvesting “entrance” point: representing how close the harvesting zone is to the village/hamlet.
2. Distance to farthest harvesting point: the farthest harvesting spot where harvesters are willing to make the effort to go to. This may also represent the end of the rattan growing area, or a point beyond which rattan only grows sparsely.
3. Mean slope : mean values of slope angle across an RHZ (in degree slope)
4. Standard deviation of slope: representing the variation in slope angle across the RHZ (in degree slope)
5. Proportion of flat slopes: slopes were classified into three classes and slopes of 5 degrees or lower were considered as flat areas; the proportion of flat slopes shows how much of the area has favourable terrain.
6. Proportion of steep slopes: steep slopes were defined as slopes greater than 20 degrees; and this represents how much of an RHZ can be considered rugged terrain that is difficult to pass through for harvesting.

4.2.3 Rattan cane harvesting activities and levels

A questionnaire survey was conducted at sampled villages, which included both open and closed questions. Rattan collection is an informal employment and information on population size in each village could only be obtained after arriving on-site at the beginning of the survey. Based on population size information from the local authority, the target number of respondents for each village was determined to be either 25% of that village’s harvester population or, if there were fewer than 30 harvesters, a minimum of 15 respondents. The selection of respondents was in the form of accidental sampling in combination with snowball sampling (Sarantakos, 2005) due to limitations in the field. In some villages, the target was not achieved, mainly due to respondents’ unavailability at the time of the survey, or in a few cases, because harvesters were reluctant to participate. It was suspected that they chose not to be interviewed because they were not sure of the legality of their activity or of their harvest destination in the forest.

The information gathered during the interview covered the following: distance and extent of rattan cane harvesting, harvesting methods, modes of transporting rattan, rattan species collected, quantity of harvested rattan for each trip, frequency and rotation of trips to the forest and perceptions of forest zones and rattan cane harvesting accessibility (see Appendix 7, Sections B.5 and B.7). An estimate of the total annual harvest per respondent was calculated from the average quantity of rattan cane harvested per respondent and the time and frequency of harvesting activity (see Appendix 7, Section B.5). A village's annual harvest was estimated by multiplying the annual individual harvest level by the number of harvesters per village and thus refers to the total annual weight of rattan canes being harvested from a particular RHZ by the harvesters from a particular village.

4.2.4 Harvesting levels and effects of accessibility and forest zone designation

Variables were grouped to investigate how accessibility and designated forest zones affect harvesting levels. Two response variables were assessed: 'individual annual harvest level' and 'village annual harvest level'. Predicting variables consist of two major groups: 'accessibility' as continuous variables and 'designated forest zones' as a categorical variable.

The seven predicting variables representing harvesting zone accessibility and size and the two response variables were checked for normality, as explained in section 3.2.2.5. Square root and $\log_{10}$ transformations were applied for the skewed data to achieve the closest-to-normal distribution.

Principal Component Analysis (PCA) is a data reduction method to obtain fewer variables that account for most of the observed variance in the original variables. PCA was conducted to try to reduce the seven predicting variables into the minimum number of variables that carry most of the information.

Multiple linear regressions were conducted for each of the response variables, i.e individual annual harvest level and village annual harvest level, to observe which predicting variables contribute significantly to the variations in response variables. To determine the best regression model, aside from observing the best regression coefficients, the AIC_c method was applied (see section 2.2.4.4). SPSS 9.0 and MS Excel were applied for the procedures.

Further testing was conducted to determine whether designated forest zones affect the levels of individual harvest level. It was considered necessary to control for the effect of accessibility factors; therefore, analysis of covariance (ANCOVA) under a univariate General Linear Model (GLM) was performed on 'individual annual harvest levels' with the accessibility variables as the covariates. Village ID was incorporated in the ANCOVA as a factor to remove the co-dependence of individual harvest levels among harvesters from the same village.

4.3 Results

4.3.1 RHZs, accessibility and adjacency to Conservation Forest

Participatory mapping was conducted in seven of the eight selected villages. PM was not possible in Lambusango Timur, because the village head did not give permission for his villagers to participate. Seven sketch maps were obtained and transferred to the respective satellite image printouts. Examples of catchment delineation, sketch map and redrawn map on satellite image printout of one site (Walompo) are given in Appendix 5 and an example of the PM in action can be seen in Figure A8.8. Given the absence of PM in Lambusango Timur, the Wakangka RHZ was assumed to approximate the Lambusango Timur RHZ.

The seven RHZs derived from PM and GIS procedures are shown in Figure 4.2. The size of each RHZ ranges from 875 ha (Kakenauwe) to 3,944 ha (Wining East), as presented in Table 4.2. Accessibility variables for each village are also shown in Table 4.1.

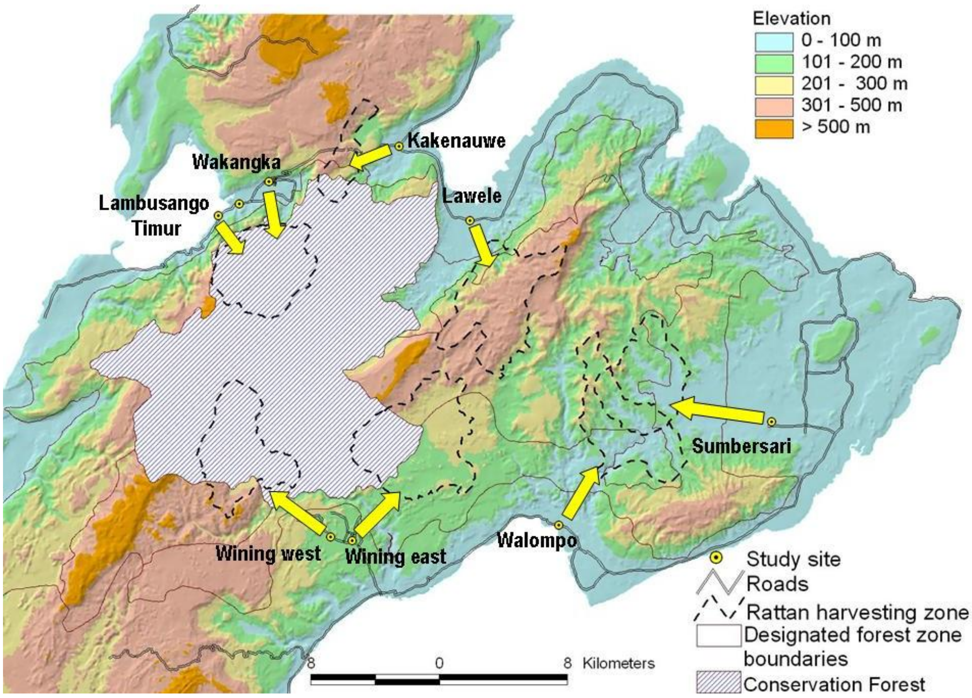


Figure 4.2. Rattan harvesting zones (RHZs) and the respective villages

Table 4.1. Rattan harvesting zones and accessibility measures extracted from GIS

Village*	Harvesting zone size (ha)	Farthest distance (m)	Shortest distance (m)	Slope mean (degree)	Slope stdv. (degree)	Proportion of flat areas	Proportion of steep areas
Lambusango Timur	2,730	6,092	2,087	14.13	8.50	0.26	0.22
Sumbersari	2,676	7,882	6,359	7.39	6.30	0.47	0.03
Wakangka	2,730	6,345	3,365	14.13	8.50	0.26	0.22
Lawele	3,157	8,163	3,914	11.08	6.73	0.32	0.08
Walompo	2,948	7,744	4,971	8.41	6.59	0.42	0.05
Wining East	3,944	7,106	4,730	4.19	4.63	0.72	0.00
Wining West	2,744	9,986	5,046	9.78	6.79	0.35	0.08
Kakenauwe	875	5,140	3,308	12.10	7.88	0.29	0.13

** Respective forest sites are presented in Table 1.1*

Terrain conditions vary across the seven RHZs. Wining East RHZ is located in the flood plain of a tributary to the Winto River and is dominated by low elevation and flat areas. This RHZ has the most favourable terrain conditions, i.e. the highest proportion of flat area (72%), no steep slopes (0%) and the lowest mean slope of 4.2 degrees. Wining West RHZ is located further west in another tributary network of the Winto River with slightly higher elevations and rougher terrain (elevation: 250-550 m asl, mean slope: 10 degrees). Walompo and Sumbersari RHZs partly overlap (Figure 4.3). Both have low elevation (< 200 m asl) but with rough terrain (mean slope: 8 degrees and slope standard deviation: 6.5 degrees). Two other RHZs with rough terrain are Lawele and Kakenauwe (mean slope: 12 degrees and slope standard deviation: 7 degrees), located at approximately 300-400 m asl. Wakangka/Lambusango Timur RHZ has the roughest terrain (mean slope of 14 degrees and standard deviation of 8.5 degrees), with the highest ratio of steep slopes (22%), located at higher elevations of 300-600 m asl.

The village with the shortest distance to the harvest area is Lambusango Timur where the RHZ begins only 2.1 km from the hamlet. The village with the farthest distance to the start of the harvest zone is Sumbersari, 6.5 km away from the settlement. For Sumbersari, recent opening of the forest for agriculture to the west of the village has increased the distance to the forest from the settlement, which in the past was only approximately 4.5 km. Harvesters who travel the farthest are those from Wining West (10 km) and those that go the shortest distance are Kakenauwe harvesters (5 km).

One RHZ is completely within the Conservation Forest (Lambusango Timur/Wakangka), three are partly within Conservation Forest (Kakenauwe, Wining East and Wining West), and three in Production Forest (Lawele, Sumbersari and Walompo).

4.3.2 Rattan cane harvesting characteristics

One hundred and eleven (111) rattan harvesters were interviewed to provide information on their harvesting activities, although for quantification of harvest level, only 89 were considered. The number of respondents and the total rattan harvester population per village is summarized in Table 4.2. The highest number of harvesters was from Sumbersari, however this does not represent the recent situation, as the last rattan cane harvesting in Sumbersari was in 2002.

Table 4.2. Number of respondents and population of rattan harvesters in the study sites

Village	Number of respondents*	Number of harvesters **
Lambusango Timur	8 (80%)	10
Sumbersari	13 (11%)	118***
Wakangka	13 (43%)	30
Lawele	18 (51%)	35
Walompo	15 (26%)	57
Wining East	7 (35%)	20
Wining West	16 (19%)	82
Kakenauwe	21 (75%)	28

* *Total number of respondents and the percentage of each village's total number of harvesters*
** *Based on information from village authorities and / or key informants in the village.*
*** *Figures represent the 2002 situation*

Six rattan species were named by harvesters as commercially valuable and are thus commonly harvested. The three most common species are: *Calamus zollingeri* (known locally as *Batang* or *Mombi*, 25-35 mm cane diameter), *Calamus ornatus* (*Lambang*, ± 20 mm cane diameter) and *Calamus sp*. (*Kabe*, 7 mm cane diameter). Three less common species are also harvested and are normally bundled together according to their diameter classes: *Calamus mindorensis* Becc. (Hoa) normally grouped with *C. zollingeri*, and *Calamus symphysipus* (*Umbul*) and *Calamus sp. Nov 2* (*Tohiti*) normally grouped with *C. ornatus*.

Rattan canes are climbers and can grow up to 40-50 meter length. Harvesters are able to identify mature rattan canes from characteristics such as peeled sheath, cane hardness, cane flexibility and colour. The harvest usually cuts mature canes into 5-7 meter lengths, except for *Calamus sp*. (*Kabe*) canes which are cut into 12-15 meter lengths.

Based on the modes of transport, rattan cane harvesting in Lambusango forest can be divided into two types: day-trip and river-rafting. For day-trip harvesting, harvesters go into the forest for between 8-12 hours on a single day. The river-rafting harvesting usually takes a few days to harvest the canes, a couple of days to bundle the canes and a couple of days to transport them with bamboo rafts to the village. The number of days in one trip varies between 10 to 15 days. This method of transport is possible in locations where the size and depth of the streams allow harvesters to push the rafts downstream and where the river network leads to a main river and outlet near the settlements (Figure A8.2). In Lore Lindu National Park, Sulawesi, logs are used for floating the canes (Siebert, 2001). In Lambusango forest bamboo is used. Day-trip harvesters are from Sumbersari, Lawele, Kakenauwe, Wakangka, Lambusango Timur and Wining West, while the river-rafting harvesters are from Walompo and Wining East.

4.3.3 Perceptions of rattan harvesting zones

60% of respondents said that their harvesting destinations are exclusively harvested by harvesters from their own village. When asked about their preference, 52% of the respondents prefer to have exclusive harvesting destinations, and 35% prefer shared-access areas. The main premise for preferring shared-access among villages is that rattan is a source of income for many villagers, so it does not feel correct to limit the sources of income in forest which belongs to all the villages surrounding Lambusango. Responses also indicate that shared-access is preferable so that harvesters are able to go to others' harvesting destinations as well.

Of all the respondents, 64 harvesters (58%) use RHZs completely or partly within the Conservation Forest. Of these 64 harvesters, only 23 (36%) correctly stated that their harvesting destination areas lay within Conservation Forest; seventeen respondents (27%) stated their harvesting destinations were in Production Forest and 20 respondents (31%) responded that they did not know the type of designated forest zone of their harvesting destinations. Four respondents did not give their responses.

There were 47 respondents (42%) from villages with RHZs completely within Production Forest. Nearly half of them (23 respondents, 48%) thought that their harvesting destinations were in the Conservation Forest; only 4 respondents (8%) correctly identified that it was in Production Forest and 16 (34%) were not aware of the type of designated forest zones they entered for harvesting. Four respondents did not respond.

4.3.4 Harvest period and frequency

The questionnaire survey also obtained information on harvesting time (hours), frequency (days per year) and harvest quantity per trip, with the intention of representing the characteristics of recent years' harvesting, i.e. 2004-2007. This intention was not entirely achieved, as rattan harvesters are not similarly active in all selected villages/hamlets. Sumbersari's harvesters mostly stopped harvesting in 2002, while for most of the other villages, in 2004-2006 rattan harvesters were still active. Villages with active harvesting during the period of observation (2007) were Walompo and Wakangka.

Villagers who are engaged in rattan harvesting normally allocate their time by considering their other livelihood activities. Since most of them are farmers, they mainly harvest rattan during off-season months in the farms. The number of days per year dedicated to rattan cane harvesting ranges from 30 to 115 days, spread over between one and twelve months a year. Harvesters from Wining West are the most persistent harvesters as they harvest 115 days per year, while Kakenauwe harvesters have the lowest frequency at 33 days per year (Table 4.3).

Table 4.3. Average days of harvesting per year

Village/hamlet	Days.yr^{-1}
Lambusango Timur	58
Sumbersari	102*
Wakangka	37
Lawele	96
Walompo	45
Wining West	115
Wining East	86
Kakenauwe	33

** Figure represents condition in 2002*

4.3.5 Rattan cane harvesting levels

Wining East and Wining West have been the most active rattan-harvesting villages, with 102 people, or approximately 27% of the household heads, engaged in rattan cane harvesting. However, the number reduced in 2006 when the asphalt mining company restarted recruitment of labourers and when some villagers migrated to Maluku province for employment.

On a day trip, a harvester usually collects one bundle of rattan canes ranging in weight from 50 to 80 kg, pulls it along the walking trails in the forest and stores the bundle in the river near the village until the selling day. River-rafting harvesters normally collect between 400-1500 kg canes per rafting trip of 10-15 days.

Harvesters from Wining East and Wining West harvest high quantities of rattan individually compared to the harvesters from other villages, approximately 6.6 ton[3] per person per year (Table 4.4). The lowest individual annual harvesting quantity is by harvesters from Kakenauwe at 2 ton per person per year. Sumbersari annual harvesting quantity does not represent the current situation and thus is not included in further analyses.

Table 4.4. Individual quantity and village quantity of rattan cane harvest

Village	Individual annual weight (kg yr^{-1})	Village annual weight (kg yr^{-1})
Lambusango Timur	2,484	24,841
Wakangka	2,919	87,579
Lawele	4,977	174,199
Walompo	3,175	181,002
Wining East	6,782	135,646
Wining West	6,588	540,254
Kakenauwe	2.045	57,273

Wining West has the highest village annual harvesting quantity of 540 ton of rattan canes. Lambusango Timur, with the lowest number of harvesters and low quantity of individual harvest, has the lowest village annual harvesting quantity of 25 ton yr^{-1}.

[3] For rattan cane, ton and kg are used as weight units; 1 ton = 10^3 kg

4.3.6 Accessibility factors that affect harvesting levels

PCA of the seven predicting accessibility variables shows that PC1 represents 73.7% of the variation in the variables (Table 4.5).

Table 4.5. Results of PCA of the seven accessibility variables

Component	Initial eigen values	
	% of variance	Cumulative %
1	73.71	73.71
2	13.72	87.43
3	10.35	97.78
4	1.51	99.3
5	0.57	99.87
6	0.13	100

Table 4.6 shows the accessibility variables and their component scores. Six variables contribute the highest scores to PC1: distance to harvest zone, RHZ size, mean slope, slope standard deviation, proportion of flat areas and proportion of steep areas. Due to the dominance and the highest scores of slope-derived variables, PC1 can be considered a ‘slope factor’ variable. PC2, with 13.7 % of the variance, predominantly represents ‘distance to farthest point’.

Table 4.6. Scores for PC1 and PC2 extracted

Variables	Component	
	1	2
Distance to farthest point	0.588	0.797
Distance to harvest zone	0.867	0.289
Harvest zone size	0.660	0.144
Mean slope	-0.963	0.253
Standard deviation of slope	-0.972	0.187
Proportion of flat areas (log_{10})	0.928	-0.341
Proportion of steep areas	-0.945	0.076

PC1 was used in subsequent multiple regressions to represent the slope factor, along with the original untransformed ‘distance to farthest point’ variable.

The best multiple linear regression model for ***individual annual harvest*** was produced by a stepwise or forward variable selection procedure. The slope factor is the only contributing variable with ‘distance to farthest point’ not being selected. The significantly strong relationship (R^2= 0.676, Adjusted R^2=0.612, F-statistics=10.45, df=1, $p=0.023$, AIC_c score=111.21) shows that the slope factor plays an important role in the variation in individual annual harvest (Figure 4.3). Statistics and AIC_c scores of different regression models are shown in Table A3.2, Appendix 3.

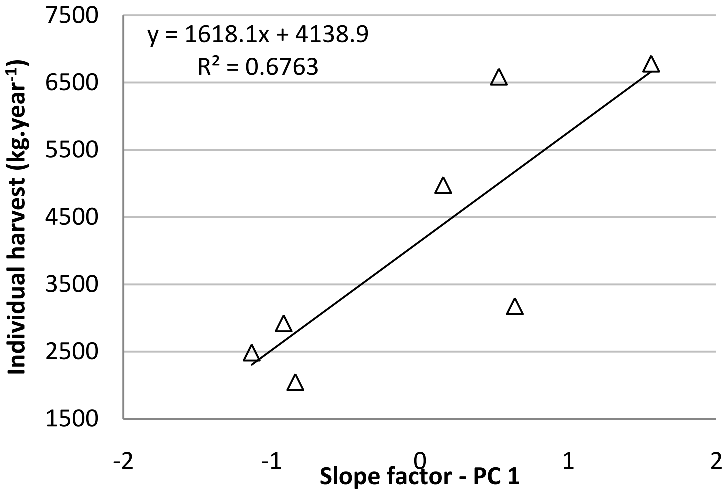


Figure 4.3. Variations in individual annual harvest quantity being explained by slope factor (PC1) (△ represents village)

For ***village annual harvest***, the best multiple regression model is produced with a stepwise, forward or backward variable selection procedure. It shows that 'distance to farthest point' best explains the variation in village annual harvest while the slope factor variable was not selected. Figure 4.4 shows a significantly strong positive relationship between village annual harvest and distance to farthest point (R^2= 0.796, Adjusted R^2=0.755, F-statistics=19.49, df=1, *p=0.007*, AIC_c score=-10.22). Statistics and AIC_c scores of different regression models are shown in Table A3.3, Appendix 3.

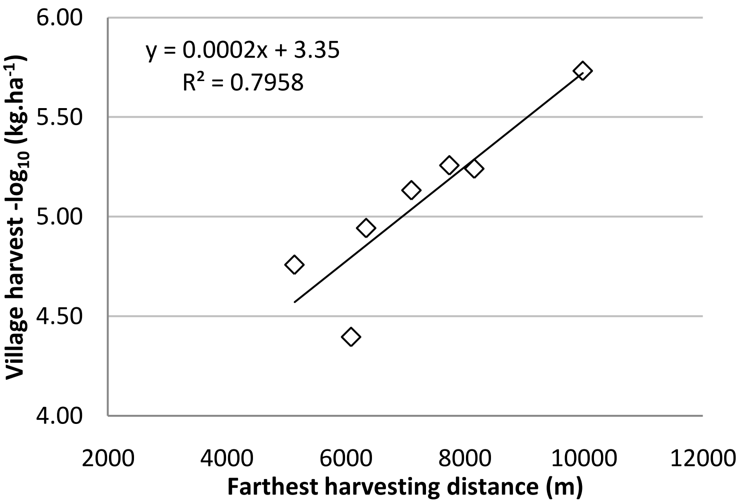


Figure 4.4. Variations in village annual harvest quantity being explained by distance to the farthest point (◇ represents village)

Harvesting zone size does not show a significant relationship with either individual annual harvest quantity or village annual harvest quantity. However, a scatter plot suggests a positive linear relationship for annual harvests of some villages (R^2=0.109, *p=0.469*) (Figure 4.5) and Wining West and Lambusango Timur are considered to be outlying cases.

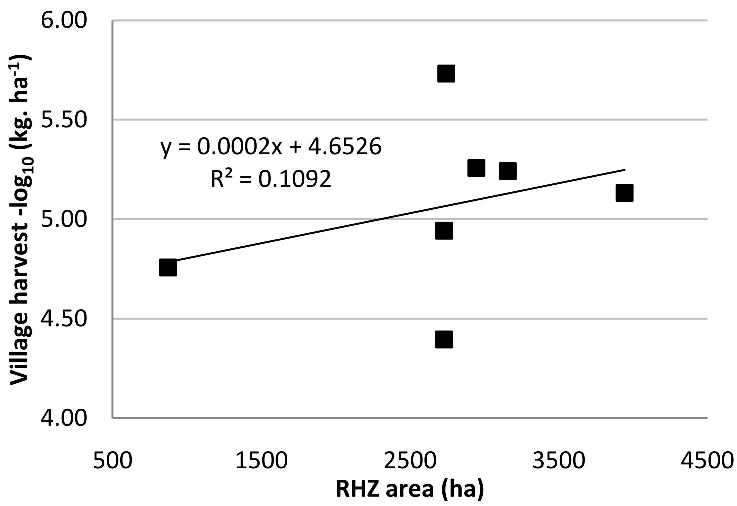


Figure 4.5. Relationship between RHZ size and village harvest quantity (■ represents village)

4.3.7 Forest zone designation affecting harvest levels

Across the three forest zones, on average, the highest individual harvest levels are by harvesters going to RHZs partly within Conservation Forest (4,538 kg yr^{-1}) followed by harvesters in Production Forest (4,136 kg yr^{-1}), and the lowest is by harvesters going into Conservation Forest (2,750 kg yr^{-1}), as shown in Table 4.7.

Table 4.7. Comparison of mean individual harvest levels among different designated forest zones

Designated forest zone	n	Mean individual weight (kg yr^{-1})	Std. error
Conservation Forest	18	2,750	460
Adjacent to Conservation forest	41	4,538	781
Production Forest	30	4,136	549

However, ANCOVA applied to the 'individual annual harvest levels' and using 'village' as a factor across the three designated forest zones indicated that by controlling both 'slope factor' and 'distance to farthest harvest point' variables, individual harvest level in the Conservation Forest will be significantly higher than in other forest zone categories (t=2.118, *p= 0.037)*. Complete parameter estimates for the ANCOVA results are in Table A3.4, Appendix 3.

4.4 Discussion

4.4.1 Rattan harvesting zones

Attempts to obtain approximate rattan harvesting zones have been made in this study, following a community-based mapping and GIS approach using a watershed metaphor for the reasoning behind rattan cane harvesting trips. The resulting RHZ boundaries based on mountain ridges should not be viewed as rigid as the delineated boundaries on the map suggest. Uncertainty in the RHZ boundaries in this study is expected, therefore the resulting boundaries should be treated as 'approximation'. Despite the crisp look in GIS, they are fuzzy in reality. Crisp boundaries are not a naturally-conceived concept in indigenous spatial knowledge (McCall, 2006). In addition, there are no rules restricting harvesters from entering other villages' harvesting destinations. It is distance and terrain conditions that serve as natural limiting factors discouraging harvesters from harvesting in other villages' rattan areas. Although fuzzy and approximate, the RHZ delineation is helpful in understanding harvesting area characteristics, resource abundance and availability in relation to where the harvesters come from and in further assessing the accessibility factors affecting harvesting activities.

Overlapping harvesting areas are likely to occur for some villages. As shown by Sumbersari and Walompo (Figure 4.2), the margins of two or more RHZs can overlap. Harvesters noted that there is an informal understanding among villagers that certain areas are core harvesting areas to particular villages, but towards the RHZ margins harvesters may come from different villages. Thus, rattan cane harvesting in Lambusango forest has a shared-access nature and is limited in distribution by rattan abundance and accessibility factors. There appear to be subtle reasons behind some harvesters' preferences for shared-access. Harvesters regard the forest as a shared area for income sources and limiting a source of income for fellow harvesters is considered unethical. Preference for shared-access is also triggered by the freedom that harvesters have been enjoying throughout their harvesting experience without any enforced regulations or law to restrict their mobility in the forest.

4.4.2 Accessibility factors affecting harvest levels

Seven variables representing accessibility have been derived from slope and distance measures to investigate whether these factors explain the variations in individual and village annual harvest quantities.

The PCA-derived slope factor shows a relationship with individual annual harvest level. Rattan cane harvesting is labour-intensive work and physically demanding. Accessibility in the forest represented by the slope factor affects the time and energy harvesters spend going into the forest and harvesting the canes. However, in these relationships it was noted that a village with a very high harvesting level (Wining West) presents an outlying case not linearly related to the slope factor. Forest in Wining West has the second highest density of rattan plants, as presented in Chapter Three, section 3.3.2, i.e 1,196 mature plants ha^{-1}. This high rattan resource abundance seems to override the effects of accessibility on harvesting levels. Despite the relatively rough topography and medium harvesting zone size, with abundant supply, a large amount of rattan cane is harvested. Other external and socio economic factors might also be influential for Wining West harvesters, such as the decline in asphalt mining production in the early 2000s that caused unemployment for former labourers (Malleson, 2005).

Several villages have low harvesting levels and do not closely fit the relationship with accessibility. Other factors may be more important for these villages. Rattan cane harvesting in the villages surrounding Lambusango forest is an informal occupation during the farm off-season. Despite its role as a cash source and livelihood safety net, rattan cane harvesting is considered labour intensive and physically demanding. Other more permanent livelihood sources in cash-crop farming may be more attractive to the villagers.

The ‘distance to farthest harvesting point’ can be considered as a surrogate for the extent of rattan abundance. The strong relationship between this predictor and village harvest quantity shows that the larger the extent of accessible rattan, the higher the quantity harvested by a village. RHZ size is a less effective surrogate for harvesting extent, reflecting that RHZ delineation is only a rough approximation, while farthest harvesting point was more accurately and specifically defined in the PM and forest survey.

4.4.3 Conservation areas in relation to harvest levels

The location of harvesting destinations in relation to designated forest zones does not appear to significantly affect the individual harvest level. Harvesters going to RHZs straddling Conservation Forest and Production Forest have the highest harvest levels. The fact that these RHZs have a high density of rattan plants and favourable topographic conditions may explain the high harvesting levels. An entry point in Production Forest may reduce awareness that their movement may have brought them into the Conservation Forest. This is worsened by the lack of clear signs or posts to indicate Conservation Forest boundaries.

Conservation areas are assumed to be a constraining factor encouraging less-intensive harvesting activity and thus lower harvest levels. It is very common that protected or conservation areas are located in the core areas of the forest which also coincide with rougher terrain. This combination makes the area less accessible or even inaccessible. Due to this combination, however, it becomes unclear which factor contributes to inaccessibility of the forest: the topography or forest regulation. In the case of Lambusango forest, it was found that by controlling the effects of slopes and extent of rattan plants, quantity of harvesting by individual cane harvester going to Conservation Forest will be higher than other forest zones. This demonstrates that the existence of the conservation area may not be a strong constraint on harvesting activity. Instead, topography and extent of rattan growth in the forest are much stronger factors.

Regardless of whether or not harvesting destinations are located in Conservation Forest, harvesters tend to state that they are aware that parts of the forest are designated as conservation areas. However, there is clearly limited understanding of Conservation Forest boundaries and whether their harvesting destinations are located inside, partly within or outside Conservation Forest. This could explain why perceptions of those harvesting in Production Forest and those harvesting partly or entirely in Conservation Forest are inconsistent with their actual harvesting destinations in relation to Conservation Forest. Harvesters also seem to have lack of awareness of the ban on forest product extraction in Conservation Forest. There is confusion between the laws restricting timber extraction in Production Forest and the laws which ban extraction or removal of any forest products in the Conservation Forest. In addition, because local communities have been harvesting forest products since long before the establishment of the designated forest zones, there is evidence of varying sentiments and reactions among villagers with regard to complying with the Conservation Forest regulations. These varying sentiments may partly be due to lack of awareness and, on top of that, a tendency to ignore the regulations when they are considered unfavorable to their livelihood activities.

Two issues emerge on the interlinkages between human activities in the forest and the establishment of conservation areas. First, establishment of Conservation Forest in areas with abundant resources in combination with good accessibility inevitably creates conflicts with local interests in forest product extraction, which is likely to lead to illegal activities. Second, to successfully enforce restricted access to resources in forest with a long-standing importance to local livelihoods, policy and regulation needs to accommodate livelihood sustainability. As reviewed by Kaimowitz and Sheil (2007), considering that local people living in the forest periphery are often poor and vulnerable, conservation efforts need to move away from a conventional approach towards a site-specific approach that also addresses poverty issues.

4.5 Conclusion

This chapter presents a case study addressing levels of rattan cane harvesting in a forest where there are conservation interests. The influences of accessibility factors and conservation designation on harvesting levels were assessed.

Boundaries of rattan harvesting zones have been derived from participatory mapping, but should be treated as an approximation of the informal areas that villages use for rattan cane harvesting activities in Lambusango forest. The application of PM/PGIS in this study proved to be an effective, objective and comprehensive tool in obtaining data and information regarding natural resource utilisation by local people.

This study has found evidence that natural factors such as terrain and accessibility have an influence on the amount harvested, due to the individual and manual nature of wild rattan cane harvesting. However, the accessibility factor is less influential where the resource is abundant and there are external factors triggering more intensive harvesting.

The forestry laws enforced through the designated forest zone system (*kawasan hutan*) do not significantly affect the levels of harvesting. In areas where forest product extraction is a long-standing and common activity, forest designations do not effectively constrain the movements of rattan harvesters. In addition, there is evidence of reluctance to recognise the relatively new conservation forest regulations. Other factors that may influence and/or explain the harvest levels are socio-economic and external factors which are examined later.

This chapter gives insight into the interlinkages between NTFP harvesting activities, forest accessibility, resource abundance and forestry laws restricting activities, and reveals associated emerging issues, hence problems, on the ground. Establishment of conservation areas and the success of enforcement need to take into account the relevant local context and issues, in addition to biological factors as the main conservation targets.

Chapter 5. Structure and species diversity of forest with conservation values affected by rattan cane harvesting

5.1 Introduction

As mentioned at the start of this thesis, most forests in the tropics have been affected by human activities to various levels (section 1.1.1). Assessments of the levels of disturbance in time and space have been conducted in many parts of the tropics, and usually in the context of concern over degrading the quality of the forest, e.g. reduced biodiversity richness. However, forest characteristics and quality are also the products of natural factors such as, among others, elevation and soils.

5.1.1 Environmental variables in tropical forest

Various environmental factors affect species abundance and composition and vegetation structure in the tropics. Elevation or altitude affects changes in temperature. An increment of 100 m elevation normally brings a temperature decrease of 0.4°-0.7° Celsius (Richards, 1981). For the Indonesian-Malay area, Mohr (1944 in Richards, 1981) classified tropical forest elevation zones to be : 0-200 m asl as lowland forest and 200-1000 asl as foothill forest, with temperatures of 25°-27° C and 19°-24° C respectively. Whitmore (1990) classified forest formations to be: 0-750 m asl as lowland forest, 750-1500 m asl as lower montane. Whitmore (1990) also classified Indonesian dipterocarp forest into: 0-300 m asl as lowland dipterocarp, 300-750 m asl as hill dipterocarp, and 750-1200 m asl as upper dipterocarp.

Understorey light plays a role in the growing environment of understorey plants, subordinate trees and tree regeneration (Brown *et al.*, 2000). Plants use part of the light spectrum for photosynthesis, known as PAR (Photosynthetically Active Radiation), which has wavelengths of 400-700 µm (Whitmore, 1990). Penetration of this light is an important factor for forest regeneration after disturbance, and therefore measures of canopy gaps have been the subject of a substantial amount of study and research (Whitmore *et al*., 1993).

Another environmental variable considered important to the variation in forest and vegetation structure is soil. The edaphic factors affecting forest plant communities in the tropics are mostly physical (Richards, 1981; Whitmore, 1990), i.e. water supplying capacity, aeration and soil depth. Most soils in tropical rainforests are low in nutrients (Richards, 1981; Whitmore, 1990), mainly due to the high downward soil water movement causing a high degree of leaching. Several studies show that the important chemical properties in tropical rain forest ecology are base deficiency, lime content, aluminium and magnesium (Richards, 1981). It was also found that clay-nutrient properties influence variations in tree biomass (Laurence *et al.*, 1999). As summarised by Schoenholtz (2000), the soil properties that are commonly applied as indicators of forest soil quality include: soil organic matter, nutrient supplying capacity, soil acidity, bulk density, porosity and available water holding capacity, and chemical properties commonly include: carbon, nitrogen, phosphorus, potassium, Cation Exchange Capacity (CEC), calcium, magnesium, pH, Salinity and Electrical Conductivity (EC) (Schoenholtz *et al*., 2000).

Slopes affect soil formation as the angle of slope has a direct effect on the rate of soil denudation. Inequilibrium between weathering and denudation causes thinner and stonier soils on steeper slopes and highly-weathered soils on gentle slopes (Young, 1976). This affects the productivity of the vegetation growing on the different slopes. Topographic factors such as slope angle and topographic position (e.g. flat ridge tops, sloping lands, valley bottom) affect tree basal area and tree density (Clark and Clark, 2000).

5.1.2 Anthropogenic factors affecting forest vegetation

The impacts of human activities on forest ecosystems vary from case to case. Activities that involve high biomass extraction substantially affect canopy cover and basal area of trees (Kumar and Shahabudin, 2005). While less severe extraction activities do not reduce basal area, they can affect understorey vegetation diversity and density (Trauernicht and Ticktin 2005; Liira *et al.*, 2007).

Past anthropogenic factors represented by different types of land use have varying effects on present vegetation structure (Romero-Duque *et al.*, 2007; Chinea and Helmer, 2003). After disturbance, regrowth produces secondary plant communities. This regrowth may range from herbs and grasses to dense forest vegetation (Richards, 1981). For forest experiencing human disturbance such as shifting cultivation, regrowth commonly occurs during the fallow period after a few crop cycles. The secondary regrowth is usually dominated by small-diameter pioneer vegetation types although it can later be invaded by species of old growth forest. Old secondary regrowth may eventually reach a climax stage with species richness and foliage development similar to those of old growth forest (Richards, 1981), as abundant shade-tolerant climax species replace fast-growing pioneer species (Whitmore, 1990). Time elapsed since the last disturbance and the types of land use prior to the secondary succession affect the present structure and composition of the forest to various extents. For example, above ground biomass and diversity of old growth forest are higher compared to younger secondary forest (Alvarez-Yepiz *et al*., 2008).

It is suspected that Lambusango forest has long been affected by human activities. There is little written and formal evidence, but based on anecdotal information, past forest dwelling occurred at least since the early 1900s up to the late 1960s. Past forest dwelling in Lambusango forest was characterised by shifting cultivation (Purwanto, 2008b). In the 1970s and 1980s a new forestry policy led to eviction of forest dwellers and resettlement in villages outside the forest (Purwanto, 2008b).

The anthropogenic influence on Lambusango forest has not ceased since then. At present, forest product extraction including rattan canes, honey and to a lesser extent timber take place in Lambusango forest (Milsom, 2004; Malleson, 2005; Purwanto, 2005a). Rattan (families of *Calamus* and *Daemonorops*) grow widely in Lambusango forest and the canes are harvested as a cash source by locals living in surrounding villages. Rattan cane was considered a major commercial NTFP from Lambusango forest in the 1990s, before the price went down and the policy regarding rattan extraction permits changed in the early-mid 2000s based on a decree from the minister of home affairs (Purwanto, 2005b).

Various studies have reported on the ecological impacts of rattan cane harvesting, in which excessive harvesting might lead to overharvesting and resource scarcity (Siebert, 2002; Evans, 2002; Sunderland and Dransfield, 2002). However, few have considered the issues of harvesting impacts on other plants and wildlife in the forest. Siebert (2002) proposed that a monitoring protocol for rattan cane sustainability should take into account indirect biological effects which include forest structure, forest succession, ecosystem nutrients and possible indirect activities such as hunting and effects of transporting the canes. The cane transportation issue emerged from studies in Lore Lindu National Park, Sulawesi, Indonesia, where timber logs were used for transporting rattan canes along the rivers (Siebert, 2002 and 2004). However, the use of logs is not common, and instead, harvesters commonly just use manual labour to carry harvested canes along trails out of the forest (e.g. in Sunderland and Dransfield, 2002). The harmful effects of rattan cane harvesting to trees and other plants in the forest are generally considered negligible (Belcher, pers. comm.; Sunderland, pers. comm.).

For Lambusango forest, the issue of continuing forest product extraction, especially rattan canes, is still questioned in terms of the sustainability of the harvesting and the ecological impacts to other flora and fauna in the forest. This concern has recently triggered efforts to assess rattan cane sustainability and conserve the forest while ensuring the livelihoods of the people living surrounding the forest. In line with those efforts, it is considered necessary to better understand forest and vegetation structure in Lambusango forest and the anthropogenic factors which might influence them.

This chapter has the overall objective of assessing tree and vegetation structure in Lambusango forest and the impacts of human activities with the emphasis on rattan cane harvesting as the largest and most intensive NTFP extraction. The specific research questions in this study are:

1. What soil properties and topographic factors affect vegetation structure, species richness and diversity?
2. Do forest vegetation structure and composition differ between rattan harvesting areas and unharvested areas and are they affected by the harvesting techniques?

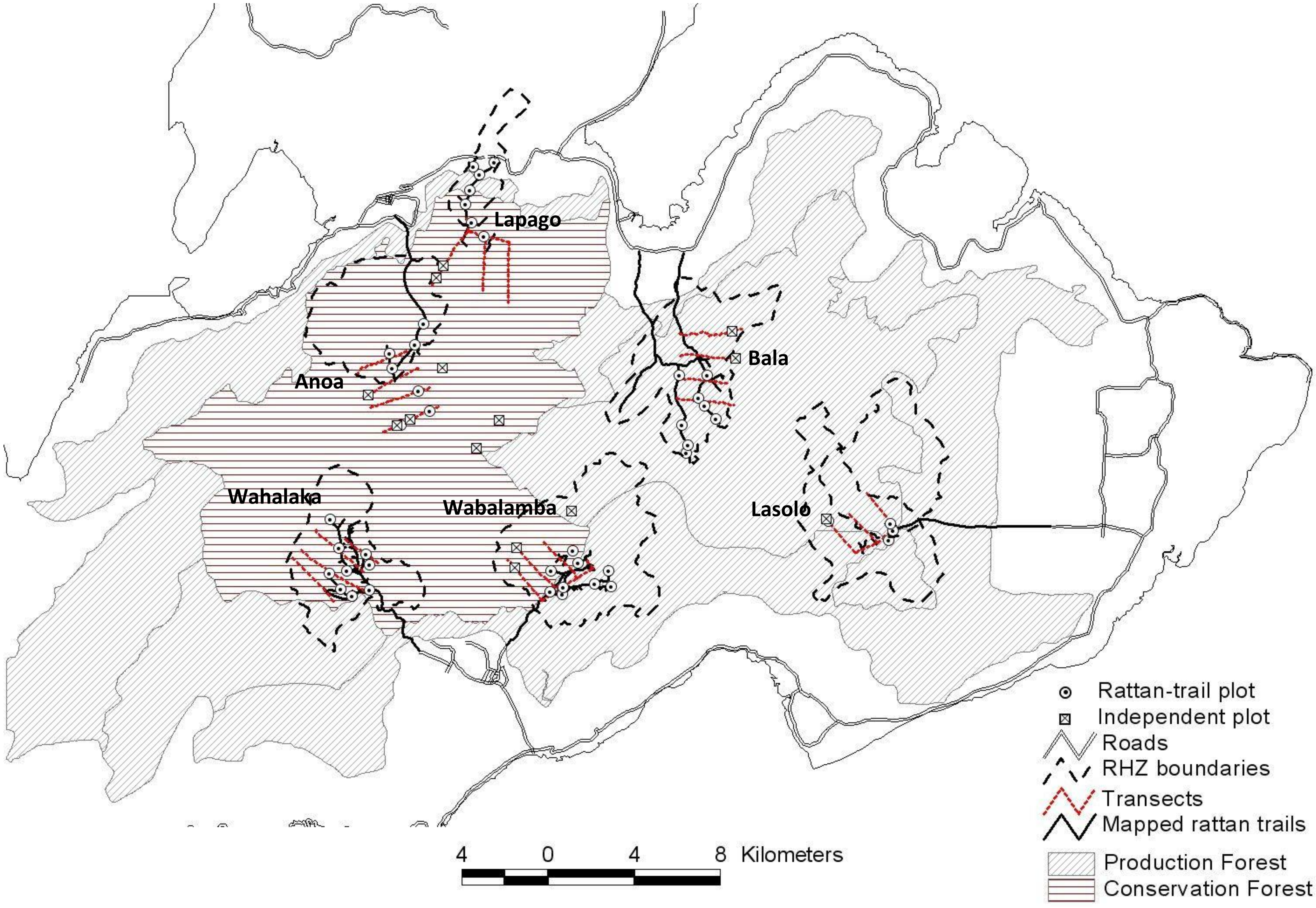


Figure 5.1. Six forest sites, with rattan trails, sample plots and RHZs

3. What are the determining factors that differentiate forest structure, in a forest with anthropogenic influences such as Lambusango forest?

5.2 Methods

5.2.1 Field sampling and data collection

The research presented in this chapter is largely based on the data collected from the sample plots as described in Chapter Three. The data used here relates to tree and understorey vegetation structure and composition, environmental variables, and impacts of rattan harvesting and timber extraction as specified below.

5.2.1.1 Tree and vegetation structure

The following tree and vegetation variables are used in this chapter, with data gathered using the methods described in Chapter Three, section 3.2.1.1. Dbh and vernacular names of trees > 5cm dbh, abundance and dbh of saplings (< 5cm dbh), abundance of seedlings (< 1.5m height), height of tallest tree for each quadrat, and cover of different layers of understorey vegetation and litter classified on site into Braun Blanquet categories.

Tree and vegetation data were also taken from a different study of forest structure in Lambusango forest conducted along transects established in the vicinity of this study sites (Carlisle, in progress). The survey was conducted by different people and one to two years prior to the survey of this study using the same plot methods and measurements. Data from these plots were considered as ‘independent plots’, i.e. independent from consideration of rattan harvesting aspects or other anthropogenic factors. There are 14 ‘independent plots’ incorporated into this study (Figure 5.1).

5.2.1.2 Collection of environmental and soil variables

The following environmental variables are used in this chapter, with data gathered using the methods described in section 3.2.1.1: altitude, slope angle and slope aspect; soil samples were also taken as described in section 3.2.1.3.

5.2.1.3 Data on anthropogenic factors from questionnaire survey

Rattan cane harvesting is the major NTFP extraction in the forest and two variables were applied to represent the rattan cane harvesting factor: rattan harvesting vicinity (RHV) and rattan harvesting impacts (RHI). RHV was determined through GIS procedures and RHI was obtained from the questionnaire survey.

Rattan harvesting vicinity (RHV) is a two-category variable: rattan harvesting area (RHA) and unharvested area (UHA). The classification of sample plots into RHA and UHA were conducted through GIS procedures in ArcView 3.2 by applying the criteria of 1) location of the plots in a core harvesting zone, around the margins or outside, 2) number of rattan plants and 3) distance to trail or river.

Figure 5.2 below summarises the procedures to determine whether sample plots belong to RHA or UHA. The analyses based on RHV were applied to the 58 sample plots, 44 being from rattan-trail plots and 14 from independent transect plots (see section 5.2.1.1). For the independent plots, since rattan canes and plants were not sampled (Carlisle, in progress), only criteria 1) and 3) are applied. The terms RHA and UHA are based on the likelihood of harvesting intensity. They do not strictly separate areas with harvesting activity from areas with no harvesting and/or no rattan grown.

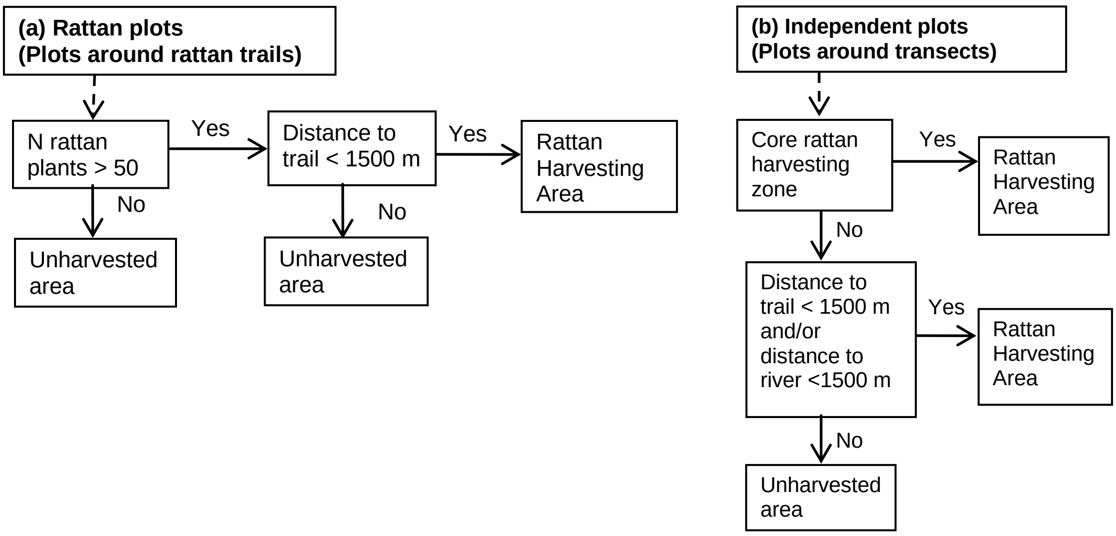


Figure 5.2. Procedures to determine the sample plots as rattan harvest area (RHA) or unharvested area (UHA): (a) for rattan plots, (b) for independent plots

Rattan harvesting impacts (RHI) represent how collectors deal with trees and vegetation surrounding rattan clumps and canes when they harvest. It is used as a surrogate to evaluate the level of damage caused by harvesting activities.

Analysis to determine rattan harvesting impacts (RHI) variables was based on respondents' answers in the questionnaire survey to a set of questions on their harvesting techniques (see Appendix 7, Section B.6.). The unit of investigation of the questionnaire survey was either village or hamlet, which was determined based on local information of where harvesters who harvest rattan canes in the six forest-rattan sites come from. There are two main points in the relevant questions: point #1 asks if a respondent will cut trees if they hamper the pulling of the rattan, and point #2 asks if a respondent tends to cut any obstructing understorey vegetation on their way to rattan areas and/or in their efforts to pull the rattan canes.

Respondents' answers were then ranked, including answers that did not exactly follow one of the choices. From this approach, three predicting sub-variables were derived: 1) harvesting impacts on trees, 2) harvesting impacts on understorey vegetation/shrubs, 3) harvesting impacts on both (trees and understorey vegetation). This information from rattan collectors was analysed to produce common values representing the level of damage at each site.

In this calculation each respondent was attributed with a dichotomous value which was based on the number of answers that fall into the highest level of damage category (rank-3). Each respondent was then categorised into 'high-impact' or 'no-to-low-impact' categories: a respondent with one or more rank-3 answer(s) is given a 'high-impact' category while a respondent with no rank-3 answer at all was given a 'no-to-low-impact' category. The proportion of high-impact respondents in each site were taken for further analyses between sites.

The RHI represents a village-level value since it comes from the proportion of high-impact respondents in a village. Further, this attribution was applied to represent levels of damage from rattan harvesting in a site harvested by respondents coming from the respective village.

Although this study does not examine timber extraction in depth and its effects on forest structure and diversity, the possibility of its effect within the rattan cane harvesting area was considered worth observing. Therefore, effects of *timber extraction vicinity (TXV)* were also taken into account, and the sample plots were assigned to two categories: timber extraction area (TXA) or no-timber-extraction area (NTA). Of the six sites, timber extraction activity was only found in the vicinity of Wabalamba. So, Wabalamba plots were designated as TXA while the plots of the other five sites were designated as NTA.

5.2.2 Variables and overall framework for analyses

The response variables to be observed can be categorised into the following: *tree structure* consisting of tree density per ha, average tree dbh, maximum tree dbh, tree above ground biomass (AGB), average height of tallest trees, maximum height of tallest trees and range of heights of tallest trees and tree crown cover; *tree species diversity* consisting of number of species, Fisher's α index and Simpson Index; and *understorey vegetation* consisting of ground vegetation cover (< 1m height), cover of second level of vegetation (1-5 m) and cover of third level of vegetation (6-20m); Litter cover and top crown cover (height > 20m) were also included.

The predicting variables can be broadly classified into: 'direct factors' and 'indirect factors' and are further explained in the following sections.

5.2.2.1 Direct factors

Direct factors consist of the biophysical characteristics of the forest, including topographical variables, soil variables and the direct anthropogenic factor. The direct anthropogenic factor is the impact caused by rattan cane harvesting activities on tree and vegetation in the area, represented by the RHI values.

Analysis of the effects of direct factors was conducted on rattan-trail plots only, not on independent plots.

The predicting variables classified as direct factors can be elaborated into the following:

Topographic variables consisting of elevation and slope angle; *Soil properties* consisting of texture, pH, fraction of C, fraction of N, CEC, Base Saturation percentage and soil macro nutrients (N, P_2O_5, K, Ca, Mg); direct anthropogenic factor of *Rattan Harvesting Impacts (RHI)*.

5.2.2.2 Indirect factors

Two types of anthropogenic factor are considered to be indirectly affecting tree structure, richness and diversity. The two indirect factors are based on the location of the study area in relation to the anthropogenic disturbance of rattan cane harvesting and timber extraction, as described by *RHV* and *TXV*.

The assessments of the indirect factors were applied to both rattan-trail plots and independent plots, and thus 58 plots were analysed.

Designated forest zone was also considered in the statistical tests, because of its possible influence as a factor limiting human activities inside the forest. However, due to the main interest being the effects of anthropogenic factors, designated forest zone was utilised as a covariate to the response variable. Sample plots and independent plots were classified into three designated forest zone categories (see Chapter One, section 1.4.1 for details):

1. Core Conservation Forest: plots around Anoa
2. Adjacent to Conservation Forest: plots around Lapago, Wahalaka and Wabalamba
3. Production forest: plots around Lasolo and Bala

Tree structure, richness and diversity were tested against all factors (topographic, direct and indirect anthropogenic factors), while understorey vegetation was tested against the indirect anthropogenic factors.

5.2.3 Analyses

The framework for all the data analyses is shown in Figure 5.3, with the application of several statistical procedures for different analyses. Details of each analysis are discussed in the sections below.

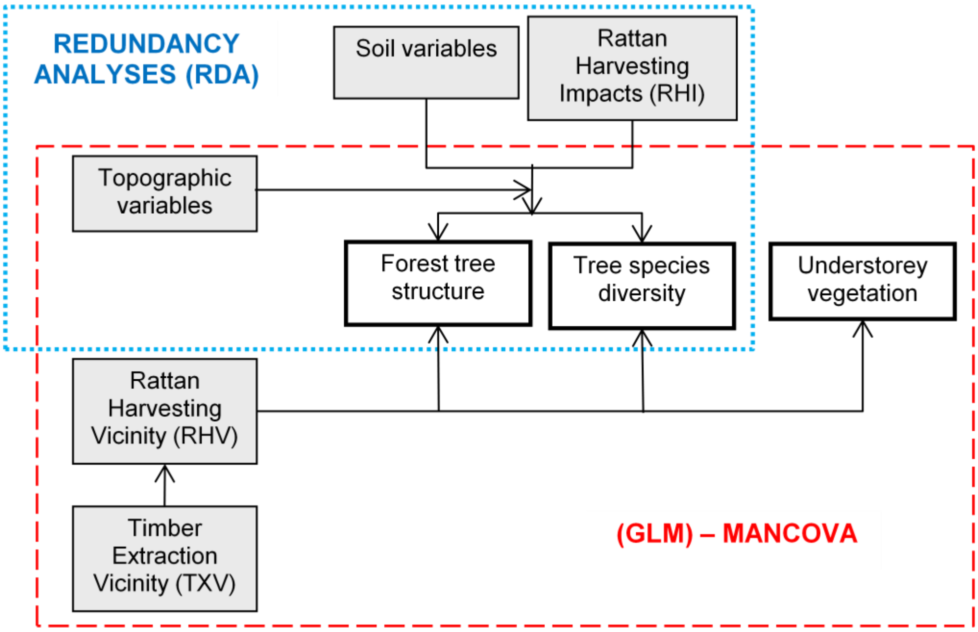


Figure 5.3. Framework of data analyses

5.2.3.1 Forest tree structure

To estimate yield, or tree aboveground biomass in this particular case, the same approaches and allometric equations as presented in Chapter Two (section 2.2.4.1, Equation 2.2) were applied. Aside from biomass, tree structure also incorporates a tree height factor. From the data on tallest tree height estimation, values from each quadrat were averaged to obtain the 'average tallest tree' in the particular plot. 'Maximum height' and the 'range of heights' were also derived; the first represents the tallest tree in the plot and the latter is a surrogate for canopy height heterogeneity.

5.2.3.2 Tree species richness and diversity calculation

Diversity measures described in section 3.2.2.2 (number of species, Fisher's α index, Simpson index and rank abundance plots) were also applied to describe tree diversity. Prior to the calculation of species richness and diversity, the vernacular names identified in the field were translated into botanical names down to species level. The reference for species identification was a tree database developed for Lambusango Forest (Widayati *et al.*, 2008). The calculation of diversity indices in this study utilised 'Species Richness and Diversity' software by Pisces Conservation, 2004. Comparison among sites was conducted using ANOVA and post-hoc comparison tests (details of methods are explained in section 3.2.2.5).

5.2.3.3 Data analyses for the relationship between tree and direct variables

A multivariate ordination method was needed to investigate any effect of the direct variables on the tree structure measures. Redundancy Analysis (RDA) is another direct gradient analysis or constrained ordination method, where the difference in species (response variables) in different sites is explained by ordination axes of environmental variables (Ter Braak, 1994; Kindt and

Coe, 2005). RDA assumes linear relationships between explanatory and response variables and it serves as the canonical equivalent of Principal Component Analyses (PCA) (Ter braak and Prentice, 1988). RDA is performed on continuous data (Palmer, 2009), and hence suits the tree structure and diversity data as the response variables in this study.

Three Anoa plots were excluded in the analyses due to their location being far beyond the rattan harvesting area or RHZ (see Chapter Four), i.e. AN3, AN4 and AN7, hence only 41 plots are included in the analysis. The exclusion avoided biases because RDA took into account impacts of harvesting, represented by RHI, which were based on harvesters' responses. These responses are relevant only for areas with rattan cane harvesting in the vicinity. Values of RHI are uniform for one site because the values obtained are village values which were then translated to the respective site.

CANOCO software (Ter Braak and Smilauer, 2002) was utilised for the execution of RDA. Tree structure and diversity measures of different units were standardised to the error variance and 1000 Monte Carlo permutation tests (Kindt and Coe, 2005) were conducted to reach appropriate levels of significance. To indicate how well the soil chemical properties and topographical variables explain the variations in tree structure and diversity variables, the sum of all canonical eigenvalues from all eigen values can be examined from the output of RDA by CANOCO (Ter Braak and Smilauer, 2002).

5.2.3.4 Data analyses for the relationship between tree and indirect variables

A General Linear Model (GLM) is an implementation of regression and ANOVA models. The application of GLM in this particular study is to conduct ***MANCOVA (Multiple Analyses of Covariance)*** to observe the main interaction effect of categorical variables on continuous response variables, while controlling the effects of other continuous variables which covary with the dependent (Garson, 2009). A set of GLM procedures was applied to observe the effects of RHV on tree and vegetation structure and composition. In this GLM procedure, the categorical predictor is RHV, and the covariates are elevation, slope and designated forest zones.

To incorporate whether effects of TXV interfere with the effects of RHV, another set of GLM procedures was conducted using RHV and TXV as predictors. Applying both RHV and TXV as predictors was chosen as opposed to making RHV a covariate, because the intention was to observe the effects of the combination of RHV and TXV, and not the effects of TXV alone by controlling RHV effects. Similarly to the GLM with RHV, in GLM procedures for RHV and TXV, elevation, slope and designated forest zone were applied as the covariates.

Prior to statistical analyses, data were checked for normality and data outside the range was considered as not-normally distributed and was transformed to achieve normality, as explained in section 3.2.2.5.

Statistical procedures for rattan cane harvesting factors were conducted in SPSS 9.0.

5.3 Results

Description of topographic and soil variables in the study area has already been presented in Chapter Three, sections 3.3.3.

5.3.1 Tree species richness and diversity

The tree and vegetation inventory was successfully conducted in 44 plots of 10*50 m^2 making a total sample area of 2.2 ha. A total of 2,121 trees were measured, among which 2,093 individuals were able to be identified to species level, 10 individuals were only identified to the vernacular names and 18 were unidentified. There are 29 families and 89 species identified. In total, the families that have the highest number of individuals are Annonaceae, Sapindaceae and Lecythidaceae which contributed 13%, 11.5% and 10.7% of the total tree abundance respectively.

The site having the highest number of tree species is Anoa, with 50 species identified, and the lowest is Lasolo, with 26 species. Number of tree species for the other sites are 47, 46, 41 and 33 for Wahalaka, Lapago, Bala and Wabalamba respectively (Table 5.1). For Fisher's α index, the highest is Anoa (15.4) and the lowest is Lasolo (8.08), and for Simpson the highest is Bala (19.4) and the lowest is Wabalamba (7.52). Figure 5.4 shows a graph of Simpson and Fisher's α indices.

Table 5.1. Number of tree species per site

Site	Species number
Anoa	50
Bala	41
Lapago	46
Lasolo	26
Wabalamba	33
Wahalaka	47

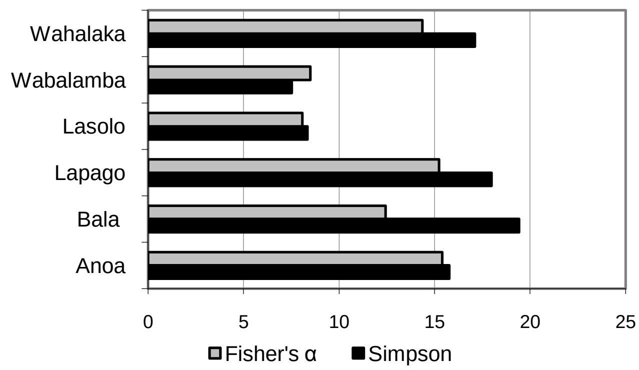


Figure 5.4. Simpson and Fisher's α indices of trees at each site

Figure 5.5 shows the rank-abundance curves of all six sites, and it can be seen that Wabalamba (WB) and Lasolo (LS) have the steepest slopes which means that there is more species dominance in those two sites. The most dominant species in Wabalamba is *Pometia spp.* (*Kase*) and *Syzygium sp.* (*Katiu*) in Lasolo, and they account for 28% and 20% of the total site tree abundance respectively. From the curve, it is seen that the other sites show relatively similar near-linear slopes which indicate high evenness in the species distribution, and thus no dominant species.

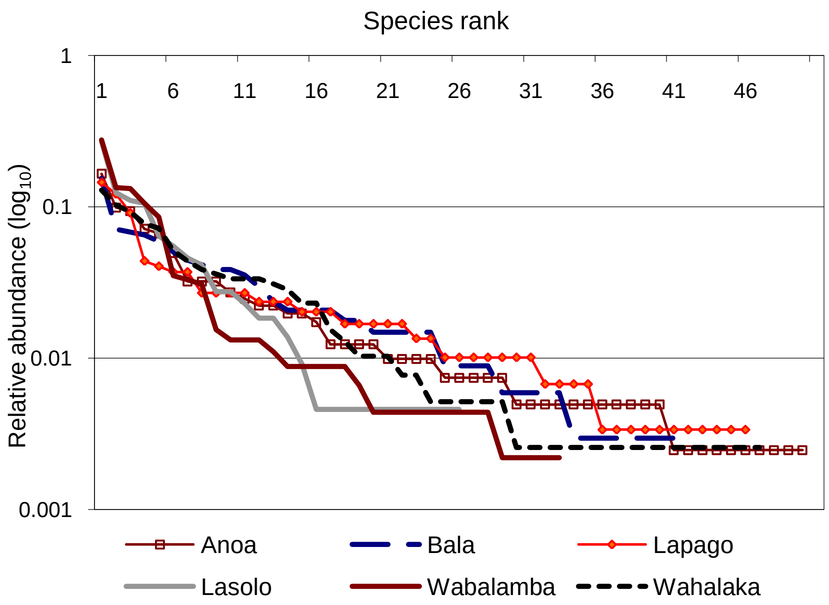


Figure 5.5. Rank-abundance plot of tree species for the six sites

5.3.2 Tree density, tree AGB and understorey vegetation

The number of trees per plot ranges from 27 up to 75 trees, giving density ranging from 540 up to 1500 trees per ha; the average density from all samples is 1,150 trees per ha. All trees with stem dbh > 5cm were measured, and the data shows that plot average stem dbh ranges from 11 to 22 cm, with the highest dbh from all the stems measured being 133 cm and 105 cm found in two plots in Wabalamba. Tree AGB of the plots ranges from 96 up to 945 Mg ha^{-1} with the average of 363 Mg ha^{-1}. The plots having the three highest tree AGB are from Wabalamba with values of above 700 Mg ha^{-1} which are substantially contributed to by the trees with the largest dbh above 90 cm, as well as by the relatively high number of trees belonging to the highest quartile among the sample plots.

The highest tree density is in Anoa (1160 trees ha^{-1}) and the lowest is in Lapago (849 trees ha^{-1}), the highest average stem dbh is in Bala (17.65 cm) and the lowest in Lasolo (13.93 cm). Maximum stem dbh from all sites is 133.7 cm and is found in Wabalamba. The site with the highest average tree AGB is Wabalamba (418 Mg ha^{-1}) and the lowest is Lapago (263 Mg ha^{-1}). The site average values of tree density, dbh and tree AGB and the maximum-dbh can be seen in Table 5.2 and the variation in Figure 5.6.

Table 5.2. Site values for average tree density, average stem dbh, maximum stem dbh and average tree AGB

Site	Avg trees ha^{-1}	Avg-dbh (cm)	Max-dbh (cm)	Avg tree AGB (Mg ha^{-1})
Anoa	1160	14.95	79.58	299.48
Bala	878	17.65	93.58	298.48
Lapago	849	16.05	57.30	236.41
Lasolo	1100	13.93	72.57	332.73
Wabalamba	1013	14.77	133.69	417.90
Wahalaka	869	17.36	94.64	365.26

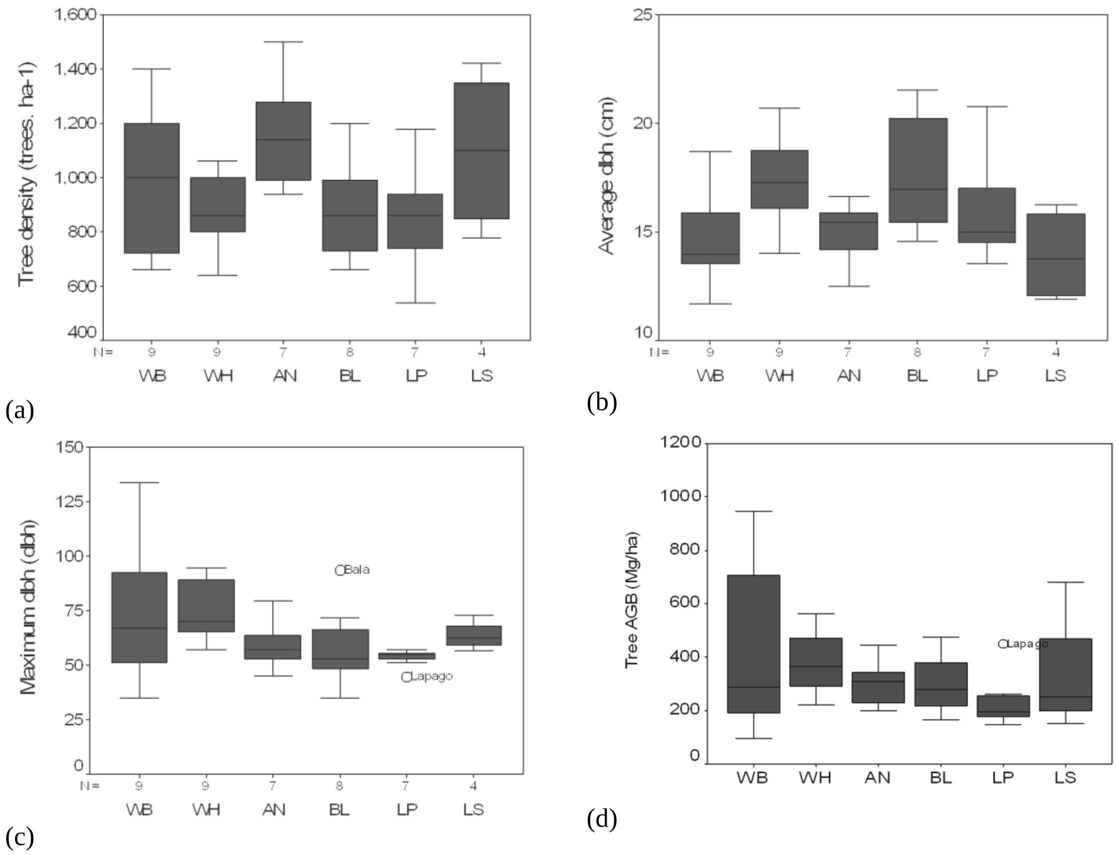


Figure 5.6. Results of each tree measure per site: (a) tree density, (b) average-dbh (c) maximum-dbh, (d) tree AGB (*Remarks: AN=Anoa, BL=Bala, LP=Lapago, LS=Lasolo, WB=Wabalamba, WH=Wahalaka)*

The average tallest trees in the plots are between 16 to 36 m, with the overall average height of 24 m. From all the sample plots, the tallest trees are estimated to be in the height range of 35-40 m and were found in seven plots from various sites. The variability of tallest trees within one plot is represented by the values of the 'range of the tallest trees'. The plots with the most homogeneous tree heights (range: 0-2.5 m) were found in Wabalamba and Lapago, and the most variable tree heights were found in three plots in Bala, Lasolo and Anoa, with a range of up to 20 m. The high range of tree heights in those plots is an indication of greater vertical gaps compared to the plots with more homogeneous tree heights.

Understorey vegetation of < 1 m height is very dense in 5 plots in Wabalamba (50-75%) and the thinnest cover is in three sites in Bala (<= 5%). For 1-5 m height, the highest cover (50-75%) is also found in 4 plots in Wabalamba and one plot in Anoa, while the thinnest cover (<10%) is found in three Lapago plots. For the understorey layer of 6-20 m height, the distribution is more varied, as there are no specific sites having many plots for either the highest cover (> 50%) or the thinnest (5-25%). The highest understoreyvegetation layer is >20 m height, and the highest cover (50-75%) is also found in various sites, and the lowest cover (5-25%) was found mostly in Wahalaka.

Results of Bonferroni and Dunnett-T3 tests show that significant differences among sites occur only for litter cover and understorey 1-5m (at $p \leq 0.05$). Litter cover is significantly higher in Lapago than in Wabalamba and Wahalaka, while understorey 1-5m is significantly higher in Wabalamba than Lapago and Lasolo.

5.3.3 Rattan harvesting impacts (RHI) on tree and vegetation

Out of 111 respondents, there were 91 respondents with valid answers for further analysis; Respondents from Sumbersari who have been mostly inactive since 2002 were not included. The breakdown for each site is shown in Table 5.3.

Table 5.3. Number of respondents for each site

Site	Nbr respondents
Wabalamba	7
Wahalaka	13
Anoa	20
Bala	18
Lapago	18
Lasolo	15

In assessing RHI, from the three components of impacts on tree, on understorey and on both, the highest proportion of the high-impact category occurred in Anoa, for tree, understorey and for both (0.3, 0.55 and 0.6 respectively). For complete results, see Table 5.4.

Table 5.4. Proportions of high-impact harvesting activity in each site based on harvesters' responses

Site	No impact on tree	Impact on tree	Proportion-impact on tree	No impact on understorey	Impact on understorey	Proportion-impact on understorey	No impact on both	Impact on both	Proportion-impact on both
Anoa	14	6	0.300	9	11	0.55	8	12	0.60
Bala	16	2	0.111	12	6	0.33	12	6	0.33
Lapago	17	1	0.056	10	8	0.44	10	8	0.44
Lasolo	13	2	0.133	7	8	0.53	7	8	0.53
Wabalamba	7	0	0.000	5	2	0.29	5	2	0.29
Wahalaka	11	2	0.154	8	5	0.38	8	5	0.38

Note: For use in statistical analyses, proportion of tree impact in Wabalamba (value=0) is given a very small value of 0.0001 to avoid failure of calculation due to zero value

5.3.4 Effects of topographic and soil variables

5.3.4.1 Relationships between tree measures and environmental measures

Ordination with RDA results in the first two axes explaining cumulatively 27 % of the total variance while the first axis alone explains 18.7 % (*$p<0.001$*). The RDA ordination biplot is shown in Figure 5.7. The two axes show the correlations of the predictors and it is seen that the dominant variables on the first axis are elevation and slope, with correlations of -0.47 and -0.36 respectively. For the second axis, dominant variables are P_2O_5, and Potassium, with correlations of 0.43 and 0.37 respectively. Correlations for all predictors and both axes are shown in Table 5.5.

Response variables on the first gradient that score highly are Simpson index and Fisher's α index at one end and tree AGB and maximum dbh at the other end. The variable scoring high on the second axis is tree average dbh. Richness and diversity of trees in Lambusango forest are shown to be affected by topographical factors of elevation and slopes. For biomass and tree size, there are indications of effects by soil chemical factors: pH and BS. Total variance explained by the explanatory variables is 39.5 % and the relationship is significant at *$p=0.042$* (Table 5.6).

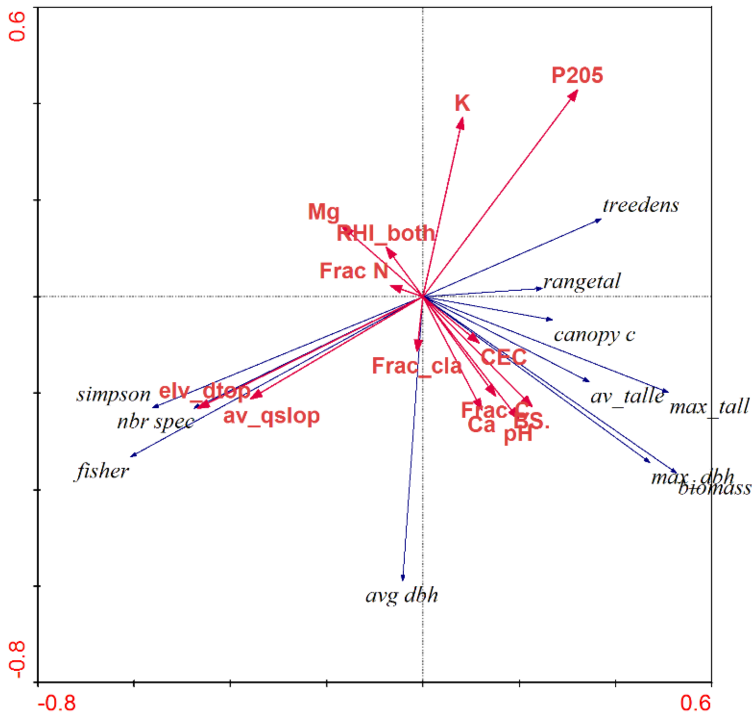


Figure 5.7. RDA biplot of tree structure-diversity variables and soil-environmental-RHI variables (Remarks: *av_talle = average height of tallest trees, avg dbh = mean of dbh, biomass = above-ground biomass, canopy c = crown cover, fisher = Fisher's α index, max_dbh = maximum dbh, max_tall = height of tallest tree, nbr spec = number of species, simpson = Simpson index, rangetall = height range of tallest trees, treedens = tree density;* for factor abbreviations see Table 5.5)

Table 5.5. Weighted correlations of environmental-soil-RHI variables resulting from RDA

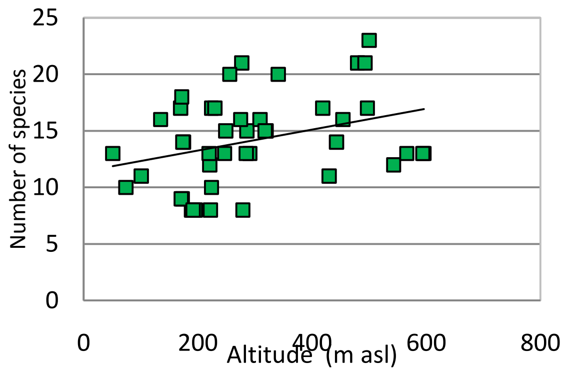
Variable	Abbreviation in biplot	Weighted correlations axis-1	Weighted correlations axis-2
Altitude (m asl)	elv_dtop	-0.4677	-0.2316
Slope (degree)	av_qslop	-0.358	-0.2118
Light regime (fraction)	Frac_cla	-0.0119	-0.1135
pH	pH	0.1991	-0.2538
Cation Exchange Capacity	CEC	0.1162	-0.0959
Carbon (fraction)	Frac C	0.1504	-0.2056
Nitrogen (fraction)	Frac N	-0.068	0.0229
Phosporus (ppm)	P205	0.3212	0.4288
Calcium (cmol (+) kg^{-1})	Ca	0.1223	-0.2353
Magnesium (cmol (+) kg^{-1})	Mg	-0.1681	0.1461
Potassium (cmol (+) kg^{-1})	K	0.082	0.3712
Base saturation (%)	BS.	0.2267	-0.2279
Rattan Harvesting Impacts	RHI_both	-0.0762	0.1019

Table 5.6. RDA summary output of tree structure and environmental-soil-RHI variables

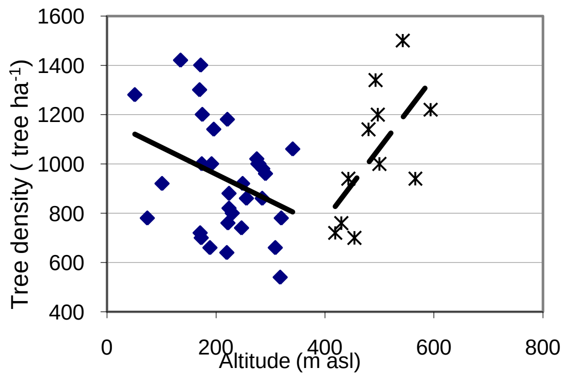
Axes	1	2	3	4	Total variance
Eigenvalues:	0.187	0.083	0.061	0.028	1
Species-environment correlations :	0.804	0.652	0.622	0.524	
Cumulative percentage variance					
of species data :	18.7	27	33.1	35.9	
of species-environment relation :	47.4	68.5	83.9	91	
Sum of all eigenvalues :					1
Sum of all canonical eigenvalues:					0.395

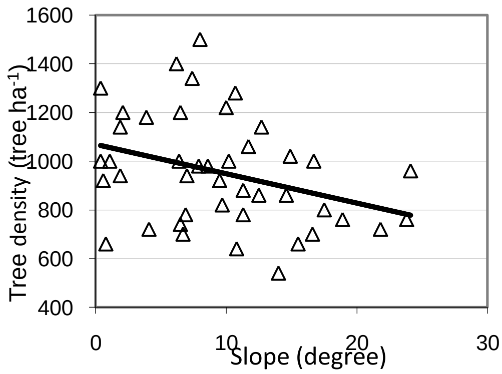
5.3.4.2 Further examination of specific relationships

Scatterplots and simple regression were used to further examine the relationships with the strongest correlations between explanatory and response variables which are shown visually in the biplot. Figure 5.8 (a) shows that altitude positively affects number of species (R^2=0.11), Figure 5.8 (b) shows two different patterns of tree density against altitude and Figure 5.8 (c) shows a negative relationship between slopes and tree density (R^2=0.11).



(a)





(b) (c)

Figure 5.8. (a) Altitude against number of species, (b) Altitude against tree density - different patterns for two ranges of altitude (< 350 m asl and > 350 m asl); and (c) Slope against tree density

5.3.5 Effects of rattan harvesting vicinity (RHV)

Of the 58 sample plots, 52 were assigned as RHA or UHA, i.e. 36 and 16 respectively.

Table 5.7 shows the significant GLM-MANCOVA results. RHV has effects on most of the measures of tree and vegetation structure and diversity. With the topographic variables as covariates, for tree measures, stem average dbh, Fisher's α index, tree density and stem maximum dbh are significantly lower in RHA compared to that in UHA and height range of tallest trees is also narrower in RHA. For understorey vegetation, for most layers (heights < 1m, 1-5m and 6-20m) the covers are significantly lower in RHA compared to those in UHA. However, despite the significant differences, only a small portion of the variations are well explained by RHV (i.e. most $eta^2 < 0.3$). Only understorey vegetation covers of 1-5 m and 6-20m are relatively well explained by RHV ($eta^2 > 0.3$).

Table 5.7. Significant results of the GLM-MANCOVA between RHA and tree-vegetation measures

Predictor	Transformation	Factor	B	p-value	Eta Squared
Understorey 6-20 m	-	RHA	-25.28	0.0000**	0.4892
Understorey 1-5m	-	RHA	-21.14	0.0000**	0.3071
Stem average dbh	$\log_{10}$	RHA	-0.0718	0.0045**	0.1590
Fisher's α index	-	RHA	-0.1848	0.0067**	0.1462
Tree density	-	RHA	-193.19	0.0093**	0.1353
Height range of tallest trees	-	RHA	-5.0645	0.0128*	0.1246
Understorey < 1m	square root	RHA	-1.3079	0.0175*	0.1143
Stem maximum dbh	square root- $\log_{10}$	RHA	-0.0417	0.0356*	0.0906
Stem maximum dbh	square root- $\log_{10}$	Forest zone	0.0278	0.0373*	0.0890
Heights of tallest trees	-	Elevation	-0.0109	0.0428*	0.0844

*Note: * significant at p<0.05; ** significant at p<0.01*

The second GLM procedures tested whether, on top of RHV, TXV affects variations in tree-vegetation measures. The number of RHV plots assigned as TXA or NTA was 46. Complete significant GLM-MANCOVA results are presented in Table 5.8. Among the tested variables, for tree measures, average dbh is affected by RHV alone, maximum-dbh is affected by forest zone and elevation, and height of tallest trees is also affected by elevation. For understorey vegetation, understorey cover of 1-5 m is affected by both RHV and TXV, and understorey cover < 1m is affected by TXV. NTA contributes to lower cover of understorey of < 1m and 1-5 m.

Table 5.8. Significant results of GLM-MANCOVA between RHV-TXV and tree-vegetation measures

Predictor	Transformation	Factor	B coefficient	p-value	Eta Squared
Understorey 1-5 m	-	NTA	-29.6352	0.0004**	0.2797
Understorey 1-5 m	-	RHA	-22.6022	0.0049**	0.1861
Stem average dbh	$\log_{10}$	RHA	-0.1391	0.0057**	0.1798
Understorey 6-20 m	-	RHA	-21.7768	0.0073**	0.1706
Stem maximum dbh	square-root, $\log_{10}$	Forest zone	0.0384	0.0150*	0.1423
Understorey < 1m	square-root	NTA	-2.2847	0.0192*	0.1328
Stem maximum dbh	square-root, $\log_{10}$	Elevation	-0.0002	0.0282*	0.1176
Heights of tallest trees	-	Elevation	-0.0141	0.0295*	0.1158

*Note: * significant at p<0.05; ** significant at p<0.01*

5.4 Discussion

5.4.1 Tree structure and diversity and the contributing natural factors

In Lambusango forest where rattan grows widely, tree composition across the forest varies. Across the whole study area, the most abundant tree species is *Planchonia valida Blume* (family: Lecythidaceae, local name: Kambau) and has similar abundance (109-133 trees ha^{-1}) in five sites (Anoa, Lapago, Lasolo, Wabalamba and Wahalaka). The only site with low *Planchonia valida Blume* abundance is Bala (20 trees ha^{-1}). The second most abundant species in Lambusango is *Pometia spp.* (family Sapindaceae, local name: Kase) which is very dominant in Wabalamba (280 trees ha^{-1}) and Lasolo (120 trees ha^{-1}), but less than 100 trees ha^{-1} in other sites. *Polyalthia lateriflora* King. (family: Annonaceae, local name: Beleko) is the third most abundant species, which grows at between 23– 136 trees ha^{-1}, and is more abundant in Wabalamba, Lasolo and Anoa than the other sites. The other major species in Lambusango are *Syzygium sp.* (family: Myrtaceae, local name: Urufi putih) and *Castanopsis cf. buruana* Miq. (family: Fagaceae, local name: Ngasa). *Planchonia valida Blume* and *Pometia spp.* are found across the Malesia region and are primary forest species, while *Polyalthia lateriflora* King. and *Syzygium sp*. normally form secondary growth, in more disturbed forests. However, there is no clear indication that any of the six sites have more secondary forest species than the others.

Of the six sites, Anoa has the richest and most diverse tree species composition, shown by the highest number of species present and the highest Fisher's α index. Simpson index is highest in Bala site, where despite the lower number of species, species abundance is shared more evenly among the individuals. The lowest Simpson indices are in Wabalamba and Lasolo, which demonstrates that there is greater species dominance in these sites, as is also indicated by the slopes of the rank/abundance plots of those two sites. As mentioned previously, the dominant species in these two sites are: *Pometia spp.* in Wabalamba and *Syzygium sp.* in Lasolo. Despite the indications of differences, based on the tests conducted, species richness and diversity do not differ significantly among the six sites.

Number of species, Fisher's α index and Simpson index all score highly on the first gradient in RDA, which is explained mostly by the topographical factors of slope and altitude. The highest richness and diversity, which is positively correlated with higher altitudes and steeper slopes, might be attributed to the lower disturbance in those terrains. None of the soil chemical variables make strong contributions to variations in tree species richness and diversity.

Throughout Lambusango forest, tree-stem density is highest in Anoa while stem dbh on average is highest in Bala. Wabalamba has the highest tree AGB of 417 Mg ha^{-1}, which is contributed substantially by both the high tree density (1,013 trees ha^{-1}) and the relatively high number of big stems of > 70 cm dbh. Wabalamba houses the highest proportion of large trees of > 70 cm (3.6% of tree abundance), but the small diameter trees are also abundant in this site, so that on average the site dbh is the second smallest.

Soil chemical factors, in particular pH and base saturation, are the factors affecting tree structure measures. There are positive contributions from soil pH and base saturation on the maximum dbh and tree AGB. The macro nutrients of Potassium and Phosphate are strong soil factors on the second gradient, although none of the response variables are significantly affected by those factors. Clay content only slightly affects tree dbh. In the Amazon, Laurence *et al.* (1999) found that clayey soils -- with higher N content, organic matter and exchangeable bases -- are associated with greater tree AGB (Laurence *et al.* 1999). Tree-stem density is negatively affected by altitude and slope, although from the simple regression (Figure 5.8 (b) and (c)) the negative correlation was shown more clearly by slope, while there seem to be two patterns for tree-stem density along the elevation gradient. In lower altitudes (< 350 m asl), trees become less dense as altitude increases while in higher altitudes (> 350 m asl) the density increases with altitude. This pattern is very likely a combination of topographic effects, including distance, and human disturbance effects. Up to 350 m asl, the disturbance might be homogeneous across the altitude range, but due to higher growth in lower altitudes, tree density is higher at lower altitudes. For altitudes above 350 m asl, human disturbance probably decreases with altitude which also correlates with increasing distance into the forest. These consequently have a positive impact on tree density as altitude increases.

5.4.2 Impacts of human activities

5.4.2.1 Impacts on tree richness and diversity

Only small parts (14.6 %) of species richness variation can be explained by RHV, which is demonstrated by lower Fisher's α index in RHAs compared to that in UHAs. The combination of topographically less favourable and less disturbed areas has positive effects on the richness and diversity of tree species. Variation in tree composition across Lambusango forest, is affected more by natural factors of elevation and slope, while human disturbance represented by rattan cane harvesting affects only small parts of the variations. While there is an effect by RHV, there is no evidence of effects by the two other related factors, RHI and TXV, on species composition.

The lack of effects by TXV may indicate that the small number of samples tested is insufficient to support the common proposition of adverse effects from timber extraction on tree species richness and diversity. Other studies in different local contexts found clearer evidence of human disturbance affecting species richness (Kumar and Shahabudin, 2005). Aside from the sample size, it is considered necessary to conduct longer term or time series analyses to be able to conclude more confidently on the effects of human activities in the forest on tree species composition, i.e. by identifying changes or dynamics.

5.4.2.2 Impacts on tree structure

Focussing specifically on the impact of the direct anthropogenic factor on tree structure, there are no indications that RHI affects variation in tree density in the forest. The presence of RHA only explains a small portion of the variation in tree density. Both results demonstrate that rattan cane harvesting factors do not provide strong explanations for the variations in tree density. These non-significant effects are seen in the outcome of the RHI calculation (Table 5.4), in which in all sites, the proportion of impacts on trees is always lower than that on understorey layers.

Significant evidence that RHA adversely affects the tree structure variables only accounts for less than 20% of the variation as shown by GLM-MANCOVA results. RHAs make some contribution to lower average-dbh, lower maximum-dbh and smaller ranges of tree heights. The small percentage of variation accounted for does not provide a strong explanation of the general variations in Lambusango forest. Further, by taking into account the other indirect anthropogenic factor, TXV, in combination with RHV, most tree measures demonstrate lack of effects by being in the vicinity of timber extraction. The low proportions of the samples' variation being significantly explained by the above predictors (12% - 18%), show that the effects of those factors are considered weak. As with the effects on tree species richness and diversity, the results for tree structure are also influenced by the low number of samples in the timber extraction areas. As this study did not specifically target the effects of timber extraction, the few samples in the timber extraction vicinity are very likely not located in the core area of timber extraction.

Purwanto (2008b) indicates that rattan cane harvesting adversely affects trees because harvesters cut trees on which the canes climb. However, evidence found in this study does not confirm this. Cane harvesting techniques, as stated by the respondents, do not involve tree cutting because harvesters are not equipped nor do they have sufficient time, energy and manpower for cutting trees. These findings do not rule out all effects of harvesting techniques on trees, but the effect is limited. As is discussed later, impacts on tree structure may be consequential or indirect.

Timber extraction in Lambusango forest targets high value timber species such as Wola (*Vitex cofassus* Reinw. ex Blume), Ipi (*Intsia palembanica* Miq.), and Tompira (*Vitex pubescens* Vahl), and several other lower value timber species, such as Bangkali (*Anthocephalus macrophyllus* (Roxb.) Havil), Koronjo (*Pterocymbium javanicum* R. Br.), Kulilawa (*Cinnamomum culilaban (L.)* Pers.), Cendana (*Pterospermum javanicum*) and Bolongita (*Tetrameles nudiflora* R.Br.). Of these eight species, only four were found in the sample plots in the study area, i.e. Bangkali, Koronjo, Wola and Tompira, and with low abundance, even in Wabalamba which is known as an area of timber extraction. There were 22 or fewer individuals of each of these species found in the total sample plots, the most common being Bangkali (22 individuals in total). This shows that the sample plots included in this study may not be in the core area of timber extraction or that the density of the valuable timber trees is indeed already very low due to past extraction.

5.4.2.3 Impacts on understorey vegetation

Results demonstrate that understorey vegetation has lower cover in RHA. These results also persist in the analyses taking into account TXV, in which RHA alone contributes to the lower understorey cover. However, it is surprising that NTA also contributes to the lower understorey cover. This could be due to an overlap with RHA, so harvesting activities show effects on reduced understorey cover regardless of the presence or absence of timber extraction activities.

The effects of RHA on lower density of understorey vegetation layers are clearly shown by the results of this study. At whatever level of cane harvesting, rattan cane harvesting activities always involve clearing of shrubs on the way to and in the area of harvesting, which includes cutting tree saplings and seedlings. This can also be observed from the RHI measure showing a higher proportion of impacts on understorey compared to trees (Table 5.4). This action by harvesters affects the survival of tree seedlings which in turn implies adverse effects on tree structure. However, it should be noted that the low understorey vegetation cover in the areas where rattans are abundant could also be attributed to the understorey competition between rattan plants and other vegetation types. Harvesting techniques that involve clearing the understorey vegetation can then be considered as exacerbating the natural condition.

Although indications of a relationship were observed and consequential effects may give rise to a greater ecological impact, there is a need to conduct longer term research to find stronger evidence. To confirm the causal effects of natural factors and human disturbance on vegetation responses, long term assessment is needed rather than static analyses (Alvarez-Yepiz *et al*., 2008).

5.4.3 Other possible factors and limitations of research

Historical human disturbance or past land use in the forest can also function as a latent factor affecting the current forest structure. Historical reports indicate that human activities, including shifting cultivation and NTFP extraction of rattan and *damar* resin, took place in different forest areas in Buton in the early 1900s (Brascamp, 1920; Bouman, 1933). Shifting cultivation continued to occur until the late 1960s before eviction by the government took place (Purwanto, 2008b), while forest product extraction such as rattan cane harvesting continues until the present. The current forest structure in Lambusango is inevitably a function of forest dynamics and recovery from past utilisation and extraction. Anecdotal information implied that cultivation may have taken place both in lowland areas and less accessible higher altitudes. Some tree-crops such as coconut trees and sugar palm grow in the forest and stone foundations and graves are also found in the forest (personal observation). Attempts to assess the effects of past anthropogenic factors, involving intensive collection of historical data, were not achieved in this study. This is particularly because traditional shifting cultivation is seasonal and temporary, and hence is not recorded well. However, even without hard evidence, the findings regarding the effects of current extraction such as rattan cane harvesting should be interpreted more carefully, taking into account the possible effects of past forest dwelling.

Several outcomes from this study show a low degree of significance or low percentages for coefficients. Various factors are suspected to be the sources of gaps or weakness, which range from insufficient data, choice of field methods and types of analyses. Including soil physical properties to test the edaphic influence on vegetation in the tropical environment may lead to improved soil-tree relationships. Data from the non-rattan harvesting areas was considered limited; more balanced data for both rattan harvesting areas and non-rattan harvesting areas will allow more objective assessments regarding impacts caused by rattan harvesting. Data on harvesting impact indicators collected from the field might have been more representative of local forest variations compared to the data applied in this study which is in the form of site-wide lumped values obtained from the questionnaire survey. Factors in the field regarding time, logistics and human resources are the source of such limitations. The statistical methods chosen and the types of variables tested could also contribute to the low significance / weak correlations. Multivariate methods such as RDA should be applied cautiously, as previously discussed in section 3.4.5. Nevertheless, given the overall conditions both technically and logistically, the results of the assessments conducted in this study are considered sufficient to provide evidence and information regarding ecological impacts of rattan cane harvesting in Lambusango forest.

5.5 Summary and conclusion

This chapter has focussed on the assessment of tree and vegetation structure and diversity in a forest where conservation efforts conflict with long standing local forest product extraction. It started by examining the natural factors which may affect vegetation structure and diversity, consisting of topographical factors and soil chemical properties. The major human activity in the area is rattan cane harvesting, which has been suspected to cause adverse ecological impacts on the forest. The impacts of rattan cane harvesting on vegetation structure and diversity were assessed by also taking into account timber extraction that occurs to a lesser extent in the study area.

Tree species richness and diversity were affected primarily by topographical factors: slope and altitude, and not by the soil chemical factors tested in this study. Tree biomass and size are shown to be slightly affected by soil factors, particularly the positive effects of pH and base saturations on tree dbh and biomass.

Structure, richness and diversity in forest with continuous forest product extraction are the products of both natural and anthropogenic factors, as is the case in Lambusango forest where rattan cane has become a major NTFP. Other assessments of the ecological impacts of rattan cane harvesting have reported various results, from direct tree-cutting to the use of tree logs for cane transport. This study found that only small variations in tree structure measures can be attributed to the impacts of rattan cane harvesting. In contrast, adverse effects on understorey vegetation density including tree saplings and seedlings are shown to be stronger. This effect is suspected to work in combination with the understorey competition between rattan plants/clumps and other vegetation. The combination of natural competition and anthropogenic factors causes adverse effects on tree-stem density.

The impacts of timber extraction were also investigated. Results demonstrate that the occurrence of large trees is slightly related to the absence of timber extraction and the presence of the conservation zone. This shows that less-disturbed areas have positive impacts on tree growth towards maximum primary productivity.

This study assesses the effects of present anthropogenic factors on Lambusango forest trees and vegetation. However, it is realised that past human disturbance from forest dwelling and shifting cultivation took place in the forest at least since the early 1900s up to the late 1960s. These past activities may still influence the current forest and vegetation structure but are not represented in the quantitative assessments. Longer term study incorporating change assessments will provide a more comprehensive approach to assessing the ecological impacts of human activities in the forest.

Tree and vegetation structure are important indicators of the ecological impacts of rattan cane harvesting, but they are not the only potentially affected aspects of the forest. For forest such as Lambusango, which is conserved mainly for wildlife biodiversity, it would be appropriate to also investigate harvesting impacts on measures of wildlife species abundance and diversity.

Chapter 6. Socioeconomic characteristics affecting wild rattan cane harvesting

6.1 Introduction

The importance of NTFP as a livelihood source for forest dwelling communities has been widely discussed as reviewed in Chapter One and Chapter Four. A key point in favour of NTFP is its comparative ecological benefit over other forest product extractions which are usually more destructive and may lead to massive biomass reduction or even forest conversion. NTFP can serve the combined roles of both income generation and forest conservation. However, the livelihood role of NTFP brings issues of commercialisation, in which forest conservation objectives are put at higher risk (see Chapter Four). With the wide range of products extracted from forests and the varied intensity of extraction undertaken by forest dwelling communities, NTFP's role may range from household safety net to fully commercialised and profitable income source (Ros-Tonen and Wiersum, 2005).

Rattan cane as one NTFP serves as an income source for local people and is not for subsistence use. As discussed earlier, rattan canes are harvested in many parts of the developing world as a wild commodity extracted from forests, many of which have conservation value (Chapters Three and Four). With the pressing issues of biodiversity preservation and other ecosystem services placed on existing forest areas in the developing world and the continuing extraction of forest products by local people living in forest peripheries, discussion of dependence on NTFP has been and still is widespread.

The proportion of household income gained from NTFP extraction reflects the importance of NTFP, or NTFP dependence of a household. In some areas, NTFP dependence is low to moderate (< 50 %) (Ambrose-Oji, 2003; Mahapatra *et al*., 2005) and in others it can be moderate to high (> 50%) (Gunatilake *et al*., 1993; Shaanker *et al*., 2003; Das, 2005). Income from NTFP is especially important to poor households living around the forest (Quang and Anh, 2006). The main direction of many NTFP studies is based on the proposition that NTFP is most important to poorer households. However, some studies show that this is not always the case or at least not so straightforward. Some have noted that NTFP contributes to the income of wealthier farmers (Ambrose-Oji, 2003; Mahapatra *et al*., 2005; McElwee, 2008). For low value or subsistence NTFP, which are of direct use by the harvesters, extraction levels are normally higher in poorer households (Ambrose-Oji, 2003; Davidar *et al*., 2008), while wealthier households are able to engage in more commercial extraction (Arnold and Ruiz Perez, 2001). Shackleton and Shackleton (2006) found that the difference between the wealthier and the poorer households in NTFP use occurs at the per capita level, while there was no significant difference at the household level.

Discussion has also focussed on the background or factors that influence local people's engagement in NTFP extraction. Paumgarten (2006) noted that most NTFP extraction is a rigorous activity; therefore, differences in extraction levels may be related to natural and physical factors. Chapter Four of this thesis discussed factors of accessibility in the forest that were assumed to have effects on the levels and intensity of rattan cane harvesting. Physical components of accessibility affecting the physical effort of rattan cane harvesting were investigated, and conservation zonation as a factor assumed to limit mobility was also assessed (Chapter Four).

As small scale farmers, NTFP harvesters have a mixture of livelihood strategies and are normally engaged in diversified income sources. The differences in their demographic, social and economic characteristics may contribute to variation in their dependence, level of involvement in NTFP collection and level of financial return from extraction. Das (2005) found that a tribal/non-tribal social factor affects the level of dependence on NTFP, while others found differences in NTFP income dependence of migrants and native villagers (Ambrose-Oji, 2003; Gubbi and McMillan, 2008). Quang and Anh (2006) concluded that NTFP is more important to poor households or those which have a high dependency ratio. With regards to other livelihood options, there is evidence that NTFP dependence is reduced by the presence of alternative wage labour opportunities (McElwee, 2008), while Gubbi and McMillan (2008) found that agricultural activities are more preferable than harvesting.

This chapter aims to assess the relationship between rattan harvesters' demographic and socioeconomic characteristics and effort, income, dependence and profitability of rattan cane harvesting. Specific research questions to be addressed are:

1. What are the livelihood sources of rattan harvesters around Lambusango forest and what are the demographic and socioeconomic characteristics of rattan harvesters?
2. How great is the dependence on rattan across villages in different parts of Lambusango forest?
3. Which demographic and socioeconomic characteristics of the harvesters contribute to effort, dependence, annual income and daily net return of wild rattan cane harvesting?

6.2 Methods

6.2.1 Study site

The unit of investigation in this study is the village, as described in Chapter One, section 1.4.2.2, with the approximate zones of harvesting as defined and discussed in Chapter Four, section 4.3.1. Appendix 6 summarises some village livelihood characteristics information.

6.2.2 Data collection applying questionnaire survey with rattan harvesters

6.2.2.1 Sampling design

The respondents for the questionnaire survey are rattan harvesters who are household heads. Due to the nature of the population and limitations in the field, sampling of respondents did not rigidly apply a formal sampling strategy. Rattan collection is an informal employment and information on village population size could only be obtained when arriving on-site at the beginning of the survey. Based on information from the local authority, population size was obtained and the sample size was determined to be either 25% of the number of harvesters or, if the total number of harvesters in a particular village or hamlet is fewer than 30 people, to achieve a minimum of 15 respondents. The selection of respondents was in the form of accidental sampling in combination with snowball sampling (Sarantakos, 2005) due to limitations in the field regarding respondents' availability.

6.2.2.2 Questionnaire

Data gathering involved a questionnaire survey with structured interviews which incorporated both open-ended and close-ended questions. The questionnaire consists of two major sections: A) Household and B) Rattan Cane Harvesting (see Appendix 7).

A. Household

Basic information: this section contains questions on demographic information, among others: age, education background, main occupation, household members and ethnicity.

Household income: due to the possibility of various revenue sources, to obtain total household revenue, data was gathered on revenues from non-farm employment, farming and forest extraction other than rattan cane harvesting. Expenses information was also gathered, grouped into education expenses, main household expenses, other non-essential household/personal expenses and cost involved in the execution of the respondents work.

B. Rattan cane harvesting

Aspects of harvesting: information on different aspects of harvesting activities was gathered, including length of harvesting trip, manner of harvesting, harvesting frequency, quantity harvested and costs involved. Information on harvest quantity, time of harvesting, rattan cane price and costs involved in harvesting was later used to calculate monetary values to define revenue and eventually income from rattan cane harvesting.

Local knowledge and perception: the purpose of this section is to tap harvesters' local knowledge and wisdom on rattan regeneration and abundance and perceptions of forest designation zone and of rattan harvesting.

Data which was further used and analysed in this chapter is mainly from Section A of the questionnaire. Information from Section B was mostly used for calculations and analyses for harvest level topics presented in Chapter Four.

6.2.2.3 Execution of data gathering

The data gathering was carried out by two interviewers, the PhD student (the author) and an assistant, by doing parallel structured interviews following the questionnaire. The assistant had undertaken interview practice prior to the survey, and during data gathering in the first village, the PhD student observed the performance of the assistant to ensure the questions were expressed correctly and to minimise biases between the two interviewers. The potential for bias was considered limited because of the structured nature of the questionnaire and predominance of closed questions. Meetings between the two interviewers were conducted at the end of each day or every other day in each village to ensure consistency, clarity and completion of responses.

The first day in a village involved getting acquainted with the village authority and obtaining general information on the village and the villagers, population size and the number of rattan harvesters. Sampling size was then defined and communicated to the village authority and local contact so they could make arrangements and appointments with potential respondents. Data gathering in each village was planned to take place over four to six days and interviewers moved from one village to another in a weekly cycle. Interviews were conducted individually with each respondent, normally at the respondent’s house, at a time of day convenient to them which was usually in late afternoon or the evening after they returned from the farms. Each interview took approximately one hour to 1.5 hours and the target was for each interviewer to interview 3-4 respondents per day, and thus 6-8 respondents per day. The number of days and daily targets were adjusted according to the number of samples determined for each village.

6.2.3 Data Analyses

The major aim of the data analyses was to ascertain the demographic and socioeconomic characteristics of rattan harvesters that influence the levels of rattan cane harvesting.

6.2.3.1 Demographic and socioeconomic factors

Several measures were calculated to represent demographic and socioeconomic factors and characteristics of harvesters’ households around Lambusango forest. Demographic measures include age, education level and ethnicity of rattan harvesters. Socioeconomic measures consist of number of household members, total annual income, annual per capita income, non-rattan income, farmland ownership, total land ownership and a composite index ‘Wealth Index’.

Household members refers to the occupants in a particular household who share the same dwelling and who depend on the respondents, which normally, but not limitedly, consists of wife and children. This measure reflects the level of economic dependence of each harvester. *Total annual income* is defined as total revenue minus total cost associated with a certain economic activity (Wollenberg and Nawir, 1998). Total annual income consists of income obtained by each household from non-farm sources (e.g. factory labour, trades), agricultural activities (including farming, livestock, poultry, fishing and marine cultivation), non-rattan forest product extraction (honey collection and timber extraction) and rattan cane harvesting. *Per capita income* is defined as total annual income divided by the number of household members. *Non-rattan income* is the total income from non-rattan activities, i.e. non-farm sources, agricultural activities and non-rattan forest product extraction. Land holding commonly consists of farmland and dwelling land. In some villages, it is common to have large dwelling land where villagers plant either cash crops, food crops or both. *Total land ownership* represents the land holding capacity and is defined as total area of lands for farming and for dwelling owned by a household.

In addition to the measures described above, a composite *Wealth index* was incorporated in the analyses. The wealth index is a measure derived from household asset ownership and dwelling unit characteristics. Such an index has been widely used as a proxy for economic status where data on income and expenditure are not available (Filmer and Pritcher, 1998). This index is relevant to this study to lump the asset-based variables into a single index. The calculation of the wealth index applied Principal Component Analyses (PCA), which is a multivariate method to reduce the dimensionality of the data by extracting uncorrelated indices or components that best capture the information within the entered variables. The extracted components/indices are a result of weighted linear combination of each variable (Filmer and Pritchett, 1998; Vyas and Kumaranayake, 2006). For the Wealth Index in this study, PCA was applied to asset and dwelling data comprising (1) area of farmland, (2) area of dwelling land, (3) house size, (4) house material, (5) roof material, and (6) possession of private bathroom.

Data which was not normally distributed was transformed into $\log_{10}$ or square root (sqrt) values, and PCA was conducted using the routines in SPSS 9.0.

6.2.3.2 Rattan harvesting aspects

The rattan cane harvesting conducted by the harvesters was analysed based on the following measures: harvesting frequency, annual rattan income, income dependence on rattan and rattan harvesting return to labour (RRtL).

Harvesting frequency is the number of days per year that a respondent harvests rattan and represents the amount of effort a harvester chooses to allocate to rattan cane harvesting.

Rattan income dependence represents the importance of rattan income to household income and is calculated from rattan income divided by total income from all sources in the household on an annual basis (Equation 6.1).

$$Rattan\ dependence = \frac{Rattan\ income}{\sum income\ (rattan, non-rattan forest, farm, non-farm)} \qquad (6.1)$$

Annual rattan income is defined as annual income each harvester earns from rattan cane harvesting activity, and is calculated from the total revenue from rattan cane sales minus the direct cost involved in rattan cane harvesting such as purchasing shoes and tools. Rattan cane harvested in Lambusano is sold as raw unprocessed canes and therefore harvesters do not have costs other than simple tools for harvesting and they do not incur costs for any post-harvest processing.

Return to labour is adopted from profitability assessments of smallholder farming and is defined as *'wage rate that sets NPV (Net Present Value) to zero'* (Tomich *et al*, 1998). For this study 'Rattan return to labour' (RRtL) is defined as per-day net income of a harvester from his cane harvesting activity. This measure also reflects the profitability of rattan cane harvesting. RRtL is calculated by dividing the annual rattan income by harvesting frequency (number of days) per year.

6.2.3.3 Statistical analyses

All the variables are continuous except ethnicity which is categorical, consisting of 'native villager' and 'migrant'. Values of 0 for native villager and 1 for migrant were applied. Education level was transformed from four categories of 'no education', 'primary school', 'junior high school' and 'senior high school' into number of years of schooling, i.e. 0 years, 6 years, 9 years and 12 years respectively.

Prior to statistical analyses, all data was checked for normality and was transformed to a normal distribution whenever necessary, following the explanation in section 3.2.2.5.

Prior to statistical analyses, some variables were found to have collinearity with others, and thus were selected for inclusion or removal. For socioeconomic factors, total annual household income and annual per capita income are highly correlated (R=0.94), and *total annual income* was further used considering the relevance to represent household as the unit of analysis. The two land holding capacity measures, farmland area and total land area, are highly correlated (R=0.99). Considering that large dwelling lands are mostly utilized for growing crops, including cash crops, it was decided to use *total land ownership* to represent land holding capacity. For response variables, harvest days and *annual rattan income* also highly correlate (R= 0.905), and therefore only annual rattan income was used, as it represents both harvesting effort and financial return.

Consequently, the final set of predicting variables to be included in the statistical analyses consists of eight variables: *age, years of education, ethnicity, number of household members, total annual income, non-rattan income, total land ownership and wealth index.* The response variables of rattan cane harvesting measures are *annual rattan income, rattan income dependence and Rattan Return to Labour (RRtL).*

Two levels of analyses have been conducted: household level and across villages. Analyses at household level were conducted to determine how demographic and socioeconomic factors of each individual rattan harvester contribute (or do not contribute) to rattan dependence, rattan annual income and RRtL. Analyses across villages focused only on the relevant socioeconomic variables of the harvesters and were conducted in order to identify differences in harvesting typologies between the villages, which are assumed to represent different typologies of different locations in the Lambusango area. Mean values of village level rattan cane harvesting parameters and predicting socioeconomic variables were analysed after removing outliers and ensuring the normality of the data.

At both levels of analysis, individual harvesters and across villages, multiple linear regressions were used to identify significant relationships and contributing factors. To select the most reliable regression model, corrected Akaike Information Criterion (AIC_c) procedures were applied (see section 2.2.4.4). SPSS 9.0 and MS Excel were used for the statistic procedures and AIC_c calculations.

Finally, data on rattan cane harvesting effort and farming effort was examined, to make observations on the balance between rattan cane harvesting and farming activities.

6.3 Results

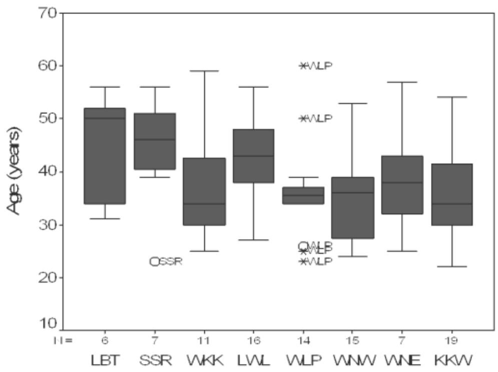
6.3.1 Socioeconomic survey of rattan cane harvesters

As is presented in Chapter Four, 111 respondents were interviewed for the survey and they represented 11%-80% of the total number of rattan harvesters for each village (see Table 4.2, in section 4.3.2). 16 respondents were excluded from the analyses for the following reasons: some respondents, mostly from Sumbersari, were not currently active harvesters and last collected rattan canes in 2001 or earlier; one respondent is not a household head; and one respondent was excluded because his answers were judged to be unreliable. The unreliability of his answers was judged from the repeated inconsistent and changing responses on the questions asked. This resulted in 95 valid respondents who were considered representative of the harvesters' current demographic and socioeconomic typologies in the villages surveyed.

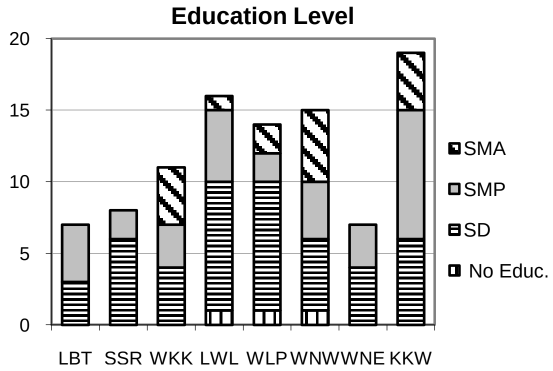
6.3.2 Comparison of demographic and socio-economic typology of harvesters by village

The average age of rattan harvesters is highest in Lambusango Timur (45 years) and lowest in Wining West, Walompo and Wakangka (36 years) (Figure 6.1(a)). In most villages, the majority of rattan harvesters' education level is primary school education (SD), except in Kakenauwe where the majority of harvesters have junior high school education (SMP) (Figure

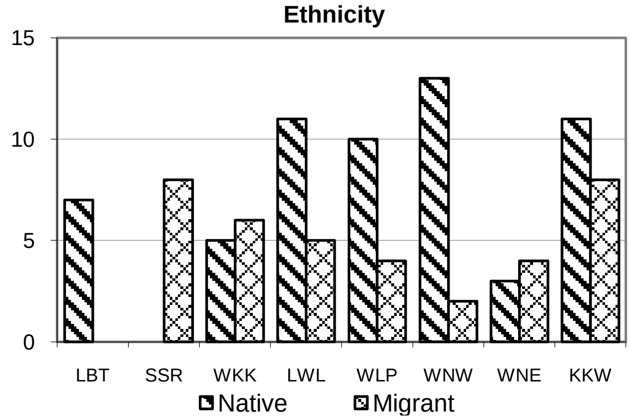
6.1(b)). In most villages, rattan harvesters are predominantly native villagers (Lambusango Timur, Lawele, Walompo, Wining West and Kakenauwe), while migrants are slightly higher in number in Wakangka and Wining East. In Sumbersari, being a transmigration settlement, all respondents are migrants of Javanese origin (Figure 6.1(c)).



(a)



(b)



(c)

Figure 6.1. Demographic typology of rattan harvesters: (a) age (b) education level and (c) ethnicity of harvesters *(LBT=Lambusango Timur, SSR=Sumbersari, WKK=Wakangka, LWL=Lawele, WLP=Walompo, WNW=Wining West, WNE=Wining East, KKW=Kakenauwe, SD=primary school, SMP=junior high school, SMA=senior high school)*

Harvesters' household income profiles for the villages can be seen in Figure 6.2, while variability of total annual income and non rattan income are shown in Figure 6.3. For total annual income of a harvester's household, the highest mean value is in Sumbersari (IDR 14 million)[4] and the lowest in Walompo (IDR 5 million). Agricultural income is also highest in Sumbersari (IDR 9 million) and lowest in Wakangka (IDR 1 million). In some villages, farming consists of both cash and subsistence crops, while in others households are only engaged in cash crop farming. As recorded from the questionnaire survey, cashew nuts, coffee, cacao and coconut are the main cash crops for rattan harvesters in many villages, while teak and ginger have just started to be grown in the past few years. Paddy rice, maize, cassava and sweet potato are grown mainly for subsistence, but also for cash if necessary.

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[4] US Dollar 1 ≈ IDR 10,000

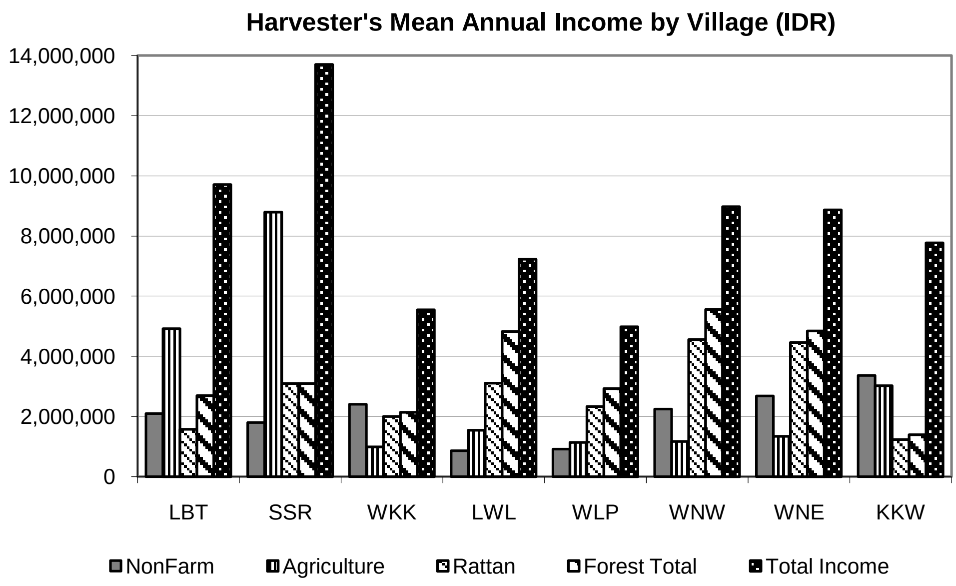
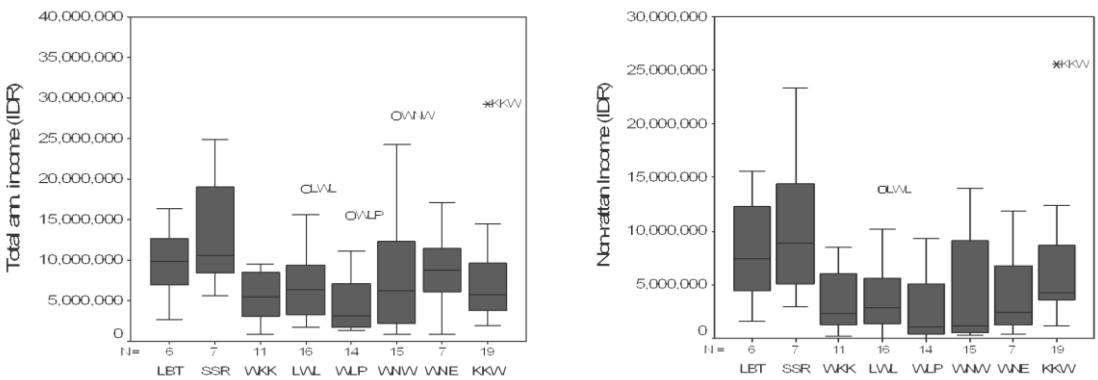


Figure 6.2. Comparison of annual income sources of rattan harvesters by village

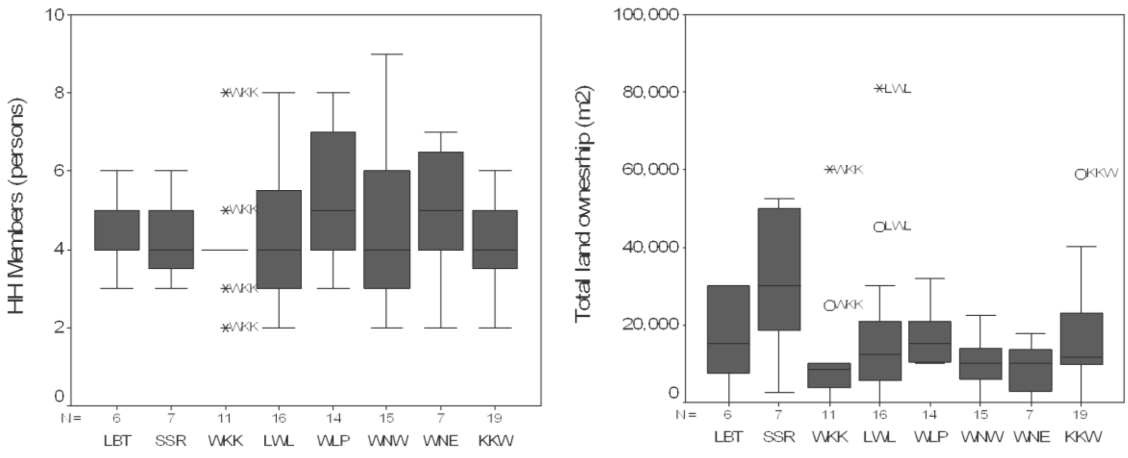
Forest income is dominated by rattan cane harvesting (60 %-100% of total forest-related income activities) in all villages. The highest mean value for forest-based income is in Wining West (IDR 5.5 million) and lowest in Kakenauwe (IDR 1.4 million). Mean non-farm income is highest in Kakenauwe (IDR 3.3 million), where harvesters are engaged as farm labours or eco tourism labours, and lowest in Lawele (IDR 850,000).



(a) (b)

Figure 6.3.Variation in (a) total annual income and (b) non rattan income between villages

Number of household members in harvesters' families varied between four and five people on average, showing that the families normally have three to four children (see Figure 6.4(a)). Total land ownership consists of farmland and dwelling land, the latter being on average one hectare or less per household. In Sumbersari, Walompo and Wining, crops or trees are usually grown on dwelling land. The highest mean value for total land ownership is in Sumbersari (3.1 ha), while the lowest mean is in Wining East (0.89 ha) (Figure 6.4(b)).



(a) (b)

Figure 6.4. Variation in (a) number of household members; (b) land ownership of the harvesters in the study sites

The wealth index from PCA procedures gave two principal components that account for 57% of the variation in the six original variables. The first component alone explains 38%. The contribution of each variable to the components is shown in Table 6.1. PC1 represents the factors of area of dwelling land, area of house land, roof quality and presence of bathroom, while PC2 represents area of farmland and wall quality. For further statistical analyses, only the first component was utilised as it has the largest amount of information common to all variables (Filmer and Pritcher, 1998).

Table 6.1. Variables contributing to the principal components

Variable	PC 1	PC 2
Farmland area (sqrt)	0.4789	-0.6085
Dwelling land area (log_{10})	0.7258	-0.2921
House land area (log_{10})	0.8211	0.0898
Wall quality	0.2185	0.781
Roof quality	0.6335	0.1577
Bathroom	0.6151	0.2586

6.3.3 Rattan harvesting efforts, dependence and financial return

After excluding Sumbersari respondents and unreliable answers, rattan harvesting measures were derived from 89 respondents.

The mean value for harvesting effort is highest in Wining West (115 days) and lowest in Kakenauwe (33 days). There are 3 villages in which harvesters dedicate a relatively high number of days in a year to harvesting, 80 days or more, i.e. Lawele, Wining West and Wining East. Harvesters in Lambusango Timur, Wakangka, Walompo and Kakenauwe spend less than 60 days harvesting rattan cane (see Figure 6.5(a)).

The mean values for annual income from rattan cane harvesting are highest in Wining West (IDR 4.55 million) and Wining East (IDR 4.46 million) and lowest in Kakenauwe (IDR 1.24

million), as shown in Figure 6.5 (b). Mean value for rattan dependence is highest in Wining West (60%) and lowest in Kakenauwe (16%). Along with Wining West, Lawele, Walompo and Wining East have a relatively high dependence on rattan, i.e. 50% or higher, are (see Figure 6.5(c)).

Mean values for rattan return to labour (RRtL) are shown in Figure 6(d). The highest RRtL values are in Wining East (IDR 58,000 per day) and Walompo (IDR 57,000 per day). The lowest RRtL values are in Lambusango Timur and Lawele (IDR 32,000 per day).

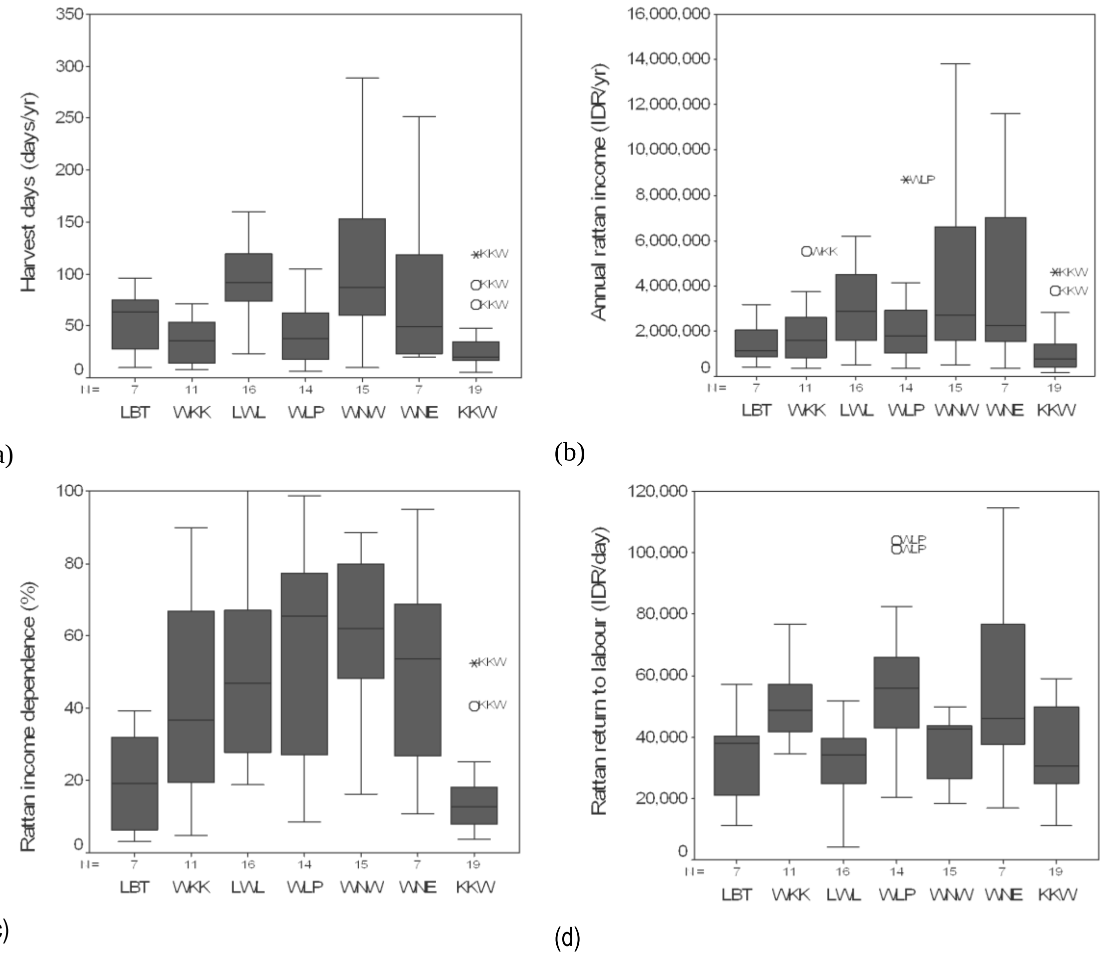


Figure 6.5. (a) Number of days of rattan cane harvesting, (b) annual rattan income, (c) rattan dependence (d) rattan return to labour (RRtL)

6.3.4 Effects of demographic and socioeconomic characteristics

For this section of analysis, the number of respondents with valid responses for both the demographic-socioeconomic information and rattan harvesting is 88.

6.3.4.1 Annual rattan income

Annual rattan income was regressed with eight predicting variables, and the best model is multiple linear regression with stepwise or forward selection. Two predictors are included, annual non-rattan income and total annual income (R^2=0.691, Adjusted R^2=0.684, F-statistics=94.07, df=2, $p< 0.001$, AIC_c score= -236.23) (Table 6.2). Statistics and AIC_c scores of different multiple linear regressions for annual rattan income are shown in Table A3.5, Appendix 3.

Table 6.2. Results of multiple regressions between annual rattan income and the predictors

	Coefficients	Std. Error	Standardised coeff.	p-value
(Constant)	-0.183	0.532		0.732
Total annual income (log_{10})	1.777	0.131	1.446	0.000
Annual non-rattan income (log_{10})	-0.867	0.085	-1.081	0.000

The strongest factor affecting annual rattan income is total annual income in a positive relationship. Figure 6.6 show the scatterplots between annual rattan income and total annual income, with annual rattan income as the predicting variable and total annual income as the response variable.

By examining the scatter plot for each village, it can be seen that the strongest positive relationships occur for Wining West, Wining East and Lawele with $R^2 \geq 0.55$ and weaker relationships occur for Walompo and Kakenauwe, with lower R^2 (approx. $0.3 < R^2 < 0.55$), while no significant relationship occurs in Wakangka and Lambusango Timur ($R^2 < 0.2$).

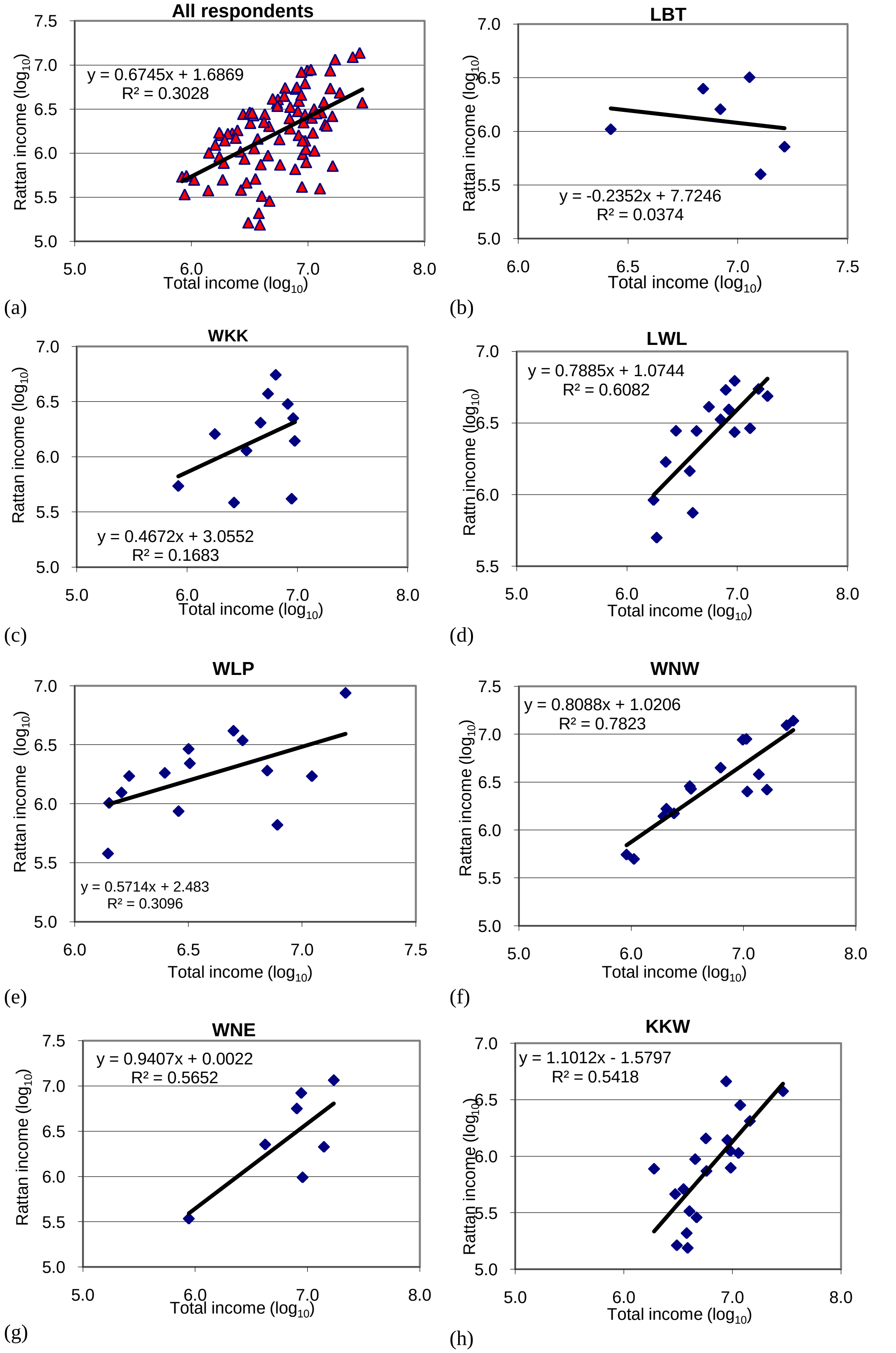


Figure 6.6. Scatter plots of total annual income and annual rattan income for (a) all respondents and (b-h) per-village respondents *(LBT=Lambusango Timur, WKK=Wakangka, LWL=Lawele, WLP=Walompo, WNW=Wining West, WNE=Wining East, KKW=Kakenauwe)*

6.3.4.2 Rattan dependence

The second response variable, ***rattan dependence***, was also regressed with the eight predictors. The best model is produced by stepwise or forward selection and two predicting variables, annual non-rattan income and total annual income, were included in the model (R^2= 0.734, Adjusted R^2=0.728, F-statistics=115.881, df=2, *p<0.001*, AIC_c=37.9) (Table 6.3). Statistics and AIC_c scores of different multiple linear regressions for rattan dependence are shown in Table A3.6, Appendix 3.

Table 6.3. Results of multiple regressions between rattan dependence and the predictors

	Coefficient	Std. Error	Standardised coeff.	p-value
Constant	7.603	2.573		0.004
Annual non-rattan income (log_{10})	-5.827	0.412	-1.397	0.000
Total annual income (log_{10})	5.320	0.631	0.832	0.000

Of the two predictors, the strongest relationship is shown by annual non-rattan income in a negative relationship, while total annual income shows weaker positive relationships. Figure 6.7 shows visually the negative relationships of annual non-rattan income and rattan dependence per village. It is seen that significant relationships ($R^2 \geq 0.55$) occur in Lambusango Timur, Wakangka and Walompo, while weaker relationships (approx. $0.3 < R^2 < 0.55$) occur in Lawele, Wining West and Wining East. No significant relationship occurs in Kakenauwe ($R^2 < 0.2$).

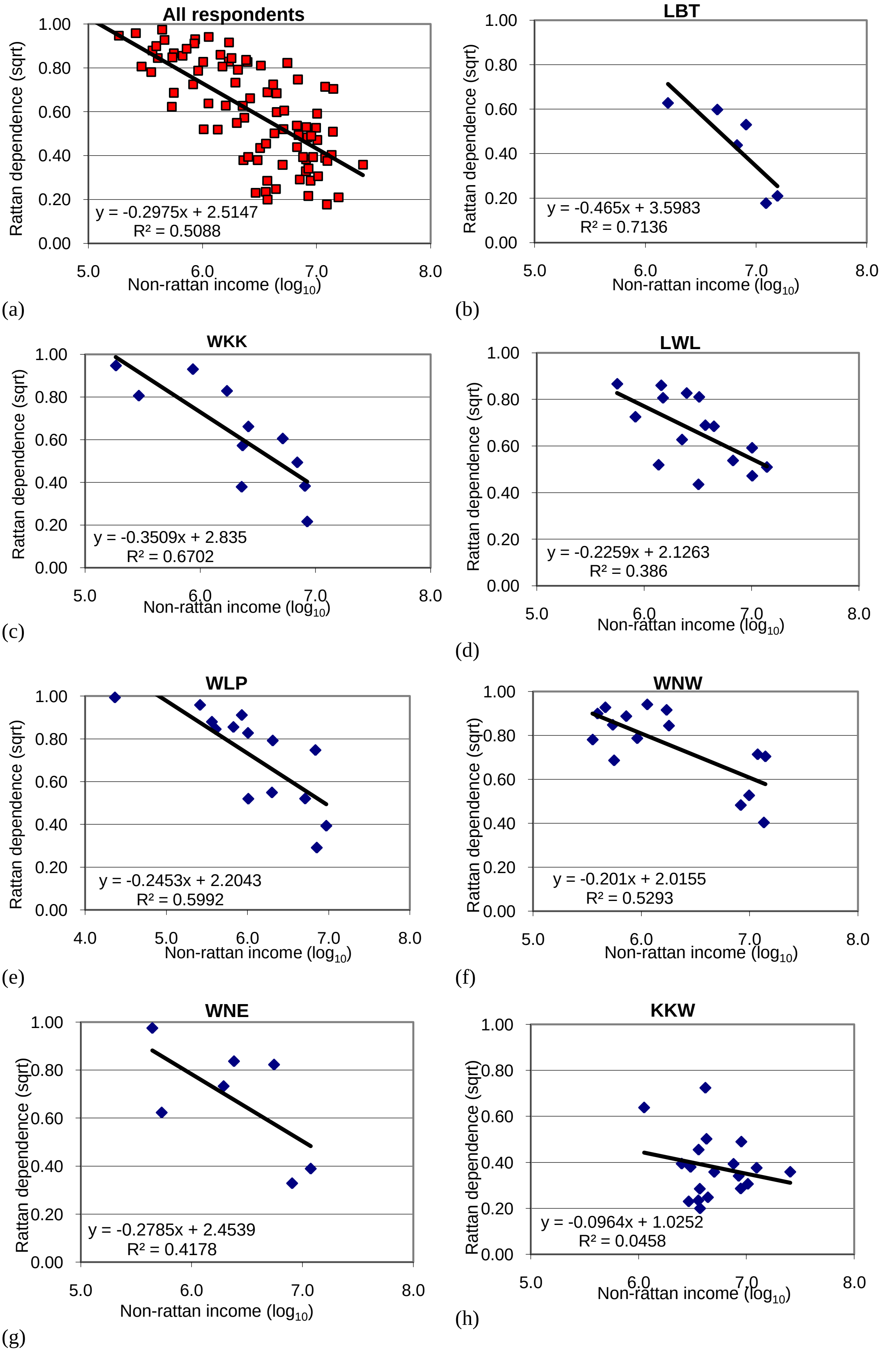


Figure 6.7. Scatter plots between annual non-rattan income and rattan dependence for (a) all respondents and (b-h) per-village respondents

6.3.4.3 Rattan return to labour (RRtL)

The third response variable assessed was ***RRtL*** and the best model is produced by multiple linear regression with stepwise selection in which two predictors, age and ethnicity, are included in the model (R^2=0.160, Adjusted R^2=0.139, F-statistics=7.970, df=2, *p=0.013*, AIC_c score=669.01). The strength of the relationship is weak, and none of the socioeconomic factors were included in the model. Statistics and AIC_c scores of different multiple linear regressions for RRtL are shown in Table A3.7, Appendix 3.

Table 6.4. Results of multiple regressions between rattan return to labour and the predictors

	Coefficient	Std. Error	Standardised coeff.	p-value
(Constant)	230.01	22.75		0.000
Age	-1.74	0.51	-0.344	0.001
Ethnicity	26.68	10.50	0.257	0.013

6.3.5 Rattan harvesting effort in relation to farming effort

Regression analysis was carried out to ascertain whether rattan cane harvesting effort is affected by effort and time allocated to farming activities. The result shows that only 12% of the variation in harvest frequency can be explained by the variation in farming months (Figure 6.8). The more farming months there are, the more varied the rattan harvest frequency is, ranging from very low to very high.

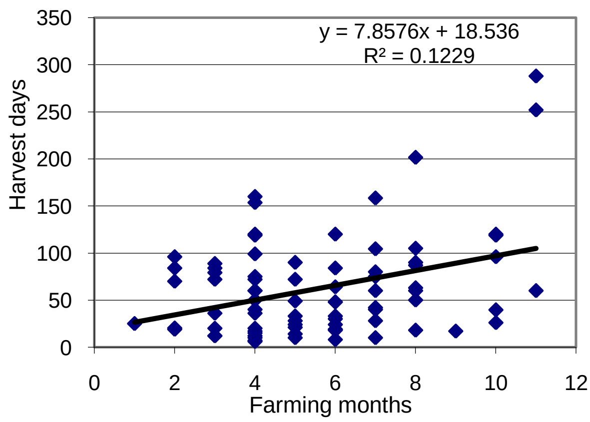


Figure 6.8. Relationship between harvest frequency and number of farming months per year

6.3.6 Relationship of the variables across villages

Village-level analysis of the harvesters was undertaken with socioeconomic predicting and response variables that are considered independent from each other. Therefore, only non-rattan income, total annual income and total land area were applied as predicting variables and annual rattan income and RRtL as response variables. None of the predicting variables were retained at *p=0.05* which shows there is no significant effect from the tested socioeconomic variables on either annual rattan income or RRtL at $p \leq 0.05$. Tests at $p \leq 0.1$ gave non-rattan income as having a significant effect on RRtL (F-statistics= 5.208, *p=0.071*) with R^2=0.51 (Figure 6.9);

there were no predictors retained in the model with annual rattan income, which means none of them are able to explain the variations in annual rattan income

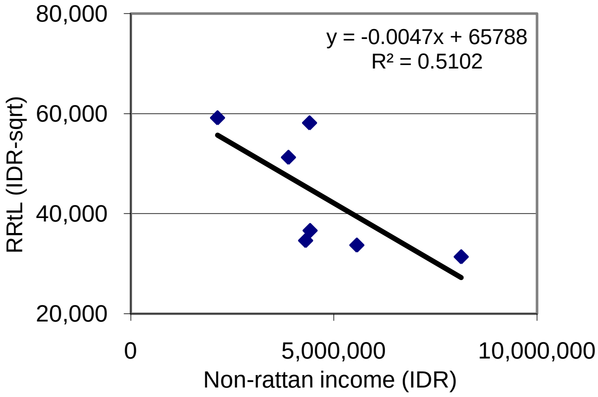
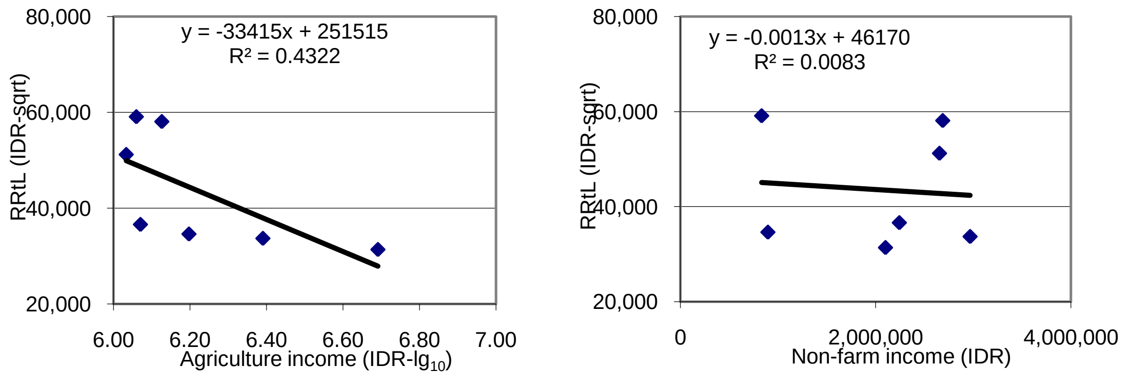


Figure 6.9. Effects of harvesters' non-rattan incomes on RRtL across villages

Since non-rattan income consists of both agricultural activities and non-farming activities, it was investigated further whether farming income or non-farm income plays a greater role in the negative effects of non-rattan income on RRtL. Figure 6.10 shows the scatter plots of both relationships. They show that agricultural income plays a stronger role with a negative relationship with RRtL, although both have low coefficients (R^2 <0.5).



(a) (b)

Figure 6.10. Effects of (a) harvesters' mean agricultural incomes and (b) harvesters' mean non agricultural incomes on RRtL across villages

6.4 Discussion

6.4.1 Livelihoods of rattan cane harvesters

Rattan cane harvesting is an informal occupation by the villagers around Lambusango forest who are mostly engaged in agricultural activities as their main livelihood. Cash-crops including cashew nuts, coffee, cacao, coconut, teak and ginger are the major commodities of the farmers in Lambusango area, and the income accounts for between 4% to 51% of total annual household income. Besides agriculture, other common sources of incomes are NTFP extraction and non-farm activities. Unlike many cases of NTFP extraction in many parts of the world where NTFPs are also extracted for subsistence or direct use by the collectors (Ambrose-Oji, 2003; Pyhala *et* *al*., 2006; Ndalangasi *et al*., 2007), in the Lambusango area, NTFP extraction is only for cash. The major extracted NTFP is rattan cane, accounting for 70% to 100% of total NTFP extracted by local people. The other NTFP which is very minor is honey. The popularity of rattan cane harvesting lies in its continuous availability in the forest, its open access and the relatively short distance for harvesting trips as if in the “backyard” of the their houses (Chapter Four). Another convenience for the local people is that buyers normally operate during off-farming seasons. Due to these various favourable factors, rattan cane harvesting fits well with local needs as an immediate cash source.

Buyers of rattan canes usually operate in major villages and set up weighing and pick-up days where they organise the collection and the transport of rattan canes sold by the harvesters. Often harvesters receive an advanced payment prior to the harvesting trips and then the payment is completed during the weighing days. In some cases the payments may be delayed until some time after the weighing days. In some villages, weighing takes place in a fixed location at the rattan processing plant, e.g. Walompo (Figure A8.3). Harvesters carry their bundles of rattan canes through streams directly to the company’s rattan processing plant which is located near the river mouth (Figure A8.2).

Besides NTFPs, forest product extraction by villagers in the area also includes timber extraction, which operates as small scale concessions. A timber extraction concession is normally owned by businessmen from the villages or major towns who employ villagers to extract and transport the timber. Timber is extracted and transported manually by local people and the transportation is along either forest paths or streams. Enquiring about timber extraction involvement appears to be sensitive due to issues around its legality. Concession permits can be more complex to implement on the ground in terms of the tonnage, area size and locations. As a result, the possibility of illegal extraction is increased. Rattan harvesters who are also engaged in timber extraction activities are mostly employed as sawn-timber porters (*buruh pikul kayu*), with none of the respondents in this study involved directly in tree cutting. However, since timber extraction is a sensitive issue due to its unclear legality, it is possible that some respondents did not want to admit to their direct involvement in timber extraction to avoid further questions which might lead to them revealing involvement in illegal activities.

Various types of non-farm income opportunities are available in the villages sampled in this study. In most of the villages, there are waged labour opportunities. Jobs are available in Wining village from asphalt mining and electric power plant companies, in Kakenauwe from the yearly eco-scientific-tourism activities and generally in all villages as traders, farm labours, brick layers, carpenters, construction labourers, basket weavers, and several other small scale opportunities. Full time waged jobs are also available in villages around Lambusango forest, although people employed in such jobs do not participate in rattan harvesting and hence were not included in this research.

6.4.2 Rattan cane harvesting typologies, demographic and socioeconomic

The four rattan cane harvesting aspects being evaluated, i.e. rattan effort, dependence, annual income and RRtL, are all highest in Wining village. Wining village has been named as having the most active rattan cane harvesting activities among villages around Lambusango forest, and it benefits from its location which is close to forest with very high rattan plant density (Chapter Three). With the division of the two sites in this village, because of the different rattan cane harvesting destinations and modes of transport (Chapter Four), effort, dependence and income are highest in Wining West, while RRtL is highest in Wining East. Besides Wining, Walompo and Lawele also represent forest-dependent villages and are considered active rattan-harvesting villages.

With the relatively uniform price of rattan canes across the villages, rattan financial returns are mainly a function of the effort expended by the harvesters through the number of harvest days per year. The greatest efforts are by harvesters in Wining West, Lawele and Wining East and they are also the three villages with the highest annual income from rattan. However, Wining East and Walompo earn the highest return to labour, IDR 58,000 and IDR 56,000 respectively. These RRtL are higher than those of Wining West and Lawele despite the lower harvest frequency. Harvesters from Wining East and Walompo use the river-rafting method for transporting harvested rattan canes (see Chapter Four). By staying longer in the forest and using bamboo rafts to transport the canes instead of pulling them manually, these harvesters are more efficient in time and transport and thus earn higher average daily returns.

Two types of daily wages are available in the villages according to the types of non-permanent labour, daily-hired labour and monthly-hired labour. The daily wage for daily-hired labour is higher than that of the monthly-hired labour, IDR 30,000-35,000 and IDR 25,000 respectively for 2005-2007. On average, RRtL is higher than these daily-hired wages, and therefore rattan cane harvesting remains an attractive alternative income source.

6.4.3 Effects of demographic factors on rattan cane harvesting

The results of this study show that demographic factors only influence ***RRtL***, and do not affect any other rattan cane harvesting variables (rattan dependence and rattan annual income). The demographic factors that contribute to the variations in RRtL are age and ethnicity, although the strength of the relationship is low (standardised beta < 0.5). The negative relationship between age and RRtL is expected due to the rigorous and manual nature of rattan cane harvesting. RRtL, which is a function of the amount of rattan canes harvested daily, reflects the need for stronger manpower to harvest more rattan canes in one day of harvesting trip. Rattan cane harvesting attracts native villagers more than migrants, which are mostly Javanese, maybe because the latter ethnic group is historically more agrarian and less forest-dependent.

Overall, considering that the other response variables of rattan effort, rattan income and rattan dependence are not affected by any of the demographic factors, the three demographic factors analysed indicate no or only weak relationships with rattan cane harvesting activities. This implies that wild rattan cane harvesting in Lambusango forest attracts people regardless of their age, educational background and whether they are native villagers or migrants.

Most respondents have middle or low educational backgrounds, indicating that such manual forest activities do not attract villagers with higher education, i.e. college educated, as they are likely to be able to have more permanent and less laborious jobs. Nevertheless, within the harvester population, variations in levels of education do not contribute to differences in effort, dependence and financial return of rattan cane harvesting.

6.4.4 Effects of socioeconomic factors on rattan cane harvesting

6.4.4.1 Effects on annual rattan income

Annual rattan income represents the effort as well as the financial return from harvesting activities. The results show that there is a positive relationship between annual rattan income and total annual income, and this occurs in most of the sampled villages. However, annual rattan income contributes to total annual income, so it should be noted that the positive relationship implies a predictive, not causal, relationship between the annual rattan income response variable and the predictor of total annual income. The positive relationship between these two variables implies the importance of rattan cane harvesting to household income. In Wining and Lawele, where this relationship is strongest, rattan cane harvesting activities have a major role in contributing to the household income.

The second significant effect on annual rattan income comes from the non-rattan income, although with lower strength (standardised beta = -1.081). The negative relationship shows that households with higher non-rattan income tend to harvest less rattan or allocate less time for harvesting and thus earn less income from rattan cane harvesting. Rattan cane harvesting, although favoured by many as a cash source, is considered laborious and requiring physical strength. Therefore, harvesters with the option to engage in more profitable and less strenuous activities reduce their time and energy spent for harvesting.

6.4.4.2 Effects on rattan dependence

A negative relationship between rattan dependence and non-rattan income is implied by the definition of rattan dependence (see section 6.2.3.2 and Equation 6.1). Multiple linear regressions confirm that non-rattan income significantly affects rattan dependence in a negative relationship. Although this does not explain exactly how the predicting variables affect the variations in response variables, it is interesting to examine how the strength of the relationship differs between villages. Rattan dependence is highest (≥ 0.4) in Wining and Lawele, and lowest in Lambusango Timur and Kakenauwe. The villages with the strongest relationships ($R^2 \geq 0.6$) between non-rattan income and rattan dependence are Lambusango Timur, Wakangka and Walompo. In Lambusango Timur and Walompo, non-rattan livelihood activities concentrate on agriculture, while in Wakangka, non-rattan income is mainly the non-farm activities of waged labour and village traders. The higher non-rattan incomes in these three villages have significant effects on the lower levels of harvesting. In Kakenauwe, there is no significant relationship between non-rattan income and rattan dependence. The low rattan dependence in Kakenauwe may occur regardless of the levels of non-rattan income because of unfavourable characteristics of the harvesting destination, which is small and predominantly within the conservation area, and the particular non-forestry sector livelihood activities available, including eco-scientific tourism.

Once again, while socioeconomic factors affecting rattan dependence were not found, the analyses led to useful discussion of variations in the roles of non-rattan income on different levels of rattan dependence across the villages.

6.4.4.3 Rattan cane harvesting and farming

There is no direct negative relationship between time spent harvesting and time spent farming. Instead, it seems that harvesters more dedicated to farming are associated with more varied time allocations for rattan cane harvesting, ranging from very low to very high number of harvesting days. The harvesting mainly takes place during the off-farming season, making it independent from farming activity. The low efforts in farming combined with low efforts in harvesting occur in villages where harvesters are engaged in other livelihood activities, such as the eco-tourism labour in Kakenauwe.

6.4.4.4. Comparison of harvesters between villages

Across villages, using a lower significance threshold ($p \leq 0.1$), there is an indication that non-rattan income of the harvesters negatively affects RRtL. Harvesters with higher income from non-rattan sources consider rattan cane harvesting as less attractive and tend to spend fewer days or less time per day harvesting and thus earn less daily return from rattan cane harvesting. Agricultural income shows stronger negative effects on RRtL than non-farm income, although both are weak relationships. Despite being independent from farming activities from a calendar perspective, low income gained from farming does seem to allow a higher daily return from rattan cane harvesting at the village level. This relationship was not found at the household level, maybe due to heterogeneity in the data. Village level values, obtained from mean values after removing outliers, may be more representative of the general socio-economic and rattan cane harvesting typologies. However, this finding is tentative due to the small number of samples both within villages as well as the number of villages (seven samples).

Rattan harvesting activities in the Lambusango area are only weakly or marginally affected by harvesters' socio-economic factors; shown by only one harvesting variable (RRtL) affected by one socioeconomic factor with low significance, as described above. Rattan cane harvesting, as is often typical of NTFP extraction, is an attractive income source that does not require capital or skill and does not interfere with farming. Limitations mostly come from factors such as a harvester's physical condition and familiarity with the forest. However, harvesters with higher income from other sources, especially from agricultural activities, indicate that they earn lower daily return from rattan cane harvesting. Although not a strong factor, better income from other livelihood sources seems to result in less interest or efforts in rattan cane harvesting. Wild rattan cane harvesting seems to involve complex decision making at the household level, a combination of circumstances and opportunities.

6.4.5 Sampling and time limitations

This study has considered demographic and socioeconomic factors which were assumed to affect various aspects of rattan cane harvesting. Non-significant or weak effects were shown by the measures tested. This study did not sample non-harvesters who are most likely from a higher economic level. Taking into account non-harvesters may give stronger evidence that rattan cane harvesting is favored by those who are less well off. However, although these additional samples could explain the position of the harvesters' economy in the wider society, they would not help to explain the variation in rattan harvest measures among harvesters.

During data collection, it was noted that livelihood activities in the villages around Lambusango are dynamic, which would affect an informal and occasional activity such as rattan cane harvesting. Data analysed in this study represent the period of 2004-2007, and relates to the time frame of forest monitoring and conservation efforts in the area, including promotion of various non-forest based livelihood activities (Purwanto, 2005b). Prior to 2004, the intensity across villages might have been different, perhaps due to other income opportunities such as asphalt mining in Wining village (Malleson, 2005), or active rattan cane harvesting in Sumbersari (Sumbersari village head, pers. comm). By the end of the study period and possibly into the future, new dynamics might be causing different patterns across the villages. These include the introduction and extension programmes of various farming commodities by Lambusango Forest Conservation Programme (LFCP) as is discussed further in Chapter Eight section 8.2.1. In Wining village, reopening of the asphalt mine was noted as an attractive livelihood option for former harvesters, as well as outmigration to the Maluku Islands for employment (Rahim, pers.comm). Therefore, the results from this study should be considered to be bound to a particular time period and be perceived as a snapshot of livelihood and forest-dependence dynamics in the Lambusango area.

6.5 Summary and conclusion

Rattan cane harvesting in the Lambusango area is an informal job additional to the main occupation, which is most commonly farming of cash crops. Non-farm jobs also exist in most of the villages with varied types of jobs and different levels of importance to the harvesters' households. The location and seasonal aspects of rattan cane harvesting make it a beneficial side income source which farmers can take advantage of during their off-farming months. Only a few of the harvesters are engaged in other forest-related activities such as timber extraction and honey collection, although due to its legality issue, it is likely that more harvesters are engaged in timber extraction than are actually recorded.

Income dependence on rattan cane among the farmers engaged in rattan cane harvesting is varied, from less than 3% up to 100% at household level and from 16% up to 53% at the village level. Villages with high dependence on rattan are Wining (East and West), Walompo and Lawele, with 50% or more dependence.

The results of this study show that demographic factors affect rattan cane harvesting activities only marginally. The implication of age effects on rattan return to labour shows that net daily income of a manual and rigorous livelihood activity such as rattan cane harvesting partly lies in the physical strength of the harvester, so younger and stronger harvesters benefit. The attraction of rattan cane harvesting as an instant cash source does not significantly differ across other demographic factors tested, i.e. educational background and ethnicity.

Dependence, annual income and daily net return from wild rattan cane harvesting in Lambusango forest are not significantly affected by the socioeconomic characteristics of the harvesters tested in this study. However, there is an indication, that in comparing harvesters across villages in the Lambusango area, higher income from non-rattan harvesting sources, especially agriculture, contributes to lower harvesting daily income. More profitable, more intensive and less rigorous livelihood activities are favoured by some harvesters.

There is concern regarding the sustainability of rattan cane harvesting as a forest product, both from the rattan demography and forest ecosystem perspectives. Efforts to ensure sustainability while maintaining the livelihood source must begin with understanding the factors that affect the levels of participation in harvesting. The lack of evidence of influencing demographic and socioeconomic factors brings questions on what does affect the levels of harvesting. Considering demographic and socioeconomic factors as internal factors, attention should also be given to external factors such as price, market, opportunity costs and policies or regulations on harvesting. In line with that, it is also important to find out what harvesters believe will encourage them to continue harvesting or what can cause them to reduce or stop harvesting. These are addressed in the subsequent chapter.

Chapter 7. Rattan cane harvesting in Lambusango forest: a viable secondary livelihood strategy?

7.1 Introduction

NTFP harvesting is a livelihood source in rural areas throughout the developing world, ranging from a livelihood safety net to a major commercialised commodity cash income. Previous studies have found varying degrees and dimensions of NTFP dependence by local people (see section 6.1). Commercial NTFPs have been widely proposed as a means to balance livelihood improvement with forest conservation by avoiding deforestation or forest conversion to a more intensive land utilization. However, the sustainability of the NTFP resources combined with environment and livelihood issues have been widely debated and various recommendations have been made (section 1.1.2.2).

Local people's dependence on NTFPs is for economic reasons. Studies have found evidence that if job alternatives are available, NTFP harvesters are willing to switch to less laborious work (Gubbi and MacMillan, 2008). This is supported by this study where rattan returns to labour are lower for harvesters who have higher incomes from other sources (see Chapter Six).

In Indonesia, most rattan cane production comes from natural forests in Sumatra, Kalimantan and Sulawesi, with only a very small amount from cultivated plants in Kalimantan (Rachman and Jasni, 2006). Livelihood issues for rattan cane harvesters resemble the typical vulnerability of NTFP collectors as discussed above, despite the fact that rattan cane has become one of the major export commodities of Indonesia (Ngakan *et al.*, 2006). Besides export, rattan canes from several outer islands in Indonesia support national furniture industries mostly located in Java. These diverse markets combined with the dynamics of trade and export policy at the national level have, one way or the other, affected the livelihoods of rattan cane harvesters, as well as the abundance and sustainability of wild rattan resources in Indonesia's forests.

National policy on rattan export in Indonesia has been changing throughout the past 35 years. During the 1970s, export of raw rattan canes was flourishing and Indonesia became the world's biggest rattan cane exporter with an average annual export of 120,000 tons, mostly as raw cane (Vantomme, 2003). In 1979 raw rattan cane export was banned (Rachman and Jasni, 2006). Until the late 1980s, national rattan production was still relatively high, up to over 80,000 tons annually, and this was suspected to be a production rush prior to the export ban policy for semi-processed cane issued in 1988 (Erwinsyah, 1999). Following the ban, national rattan cane production fell to 30,000-80,000 tons annually (Erwinsyah, 1999), while exports fell to an average of 882 tons annually (Vantomme, 2003). The change of regulation was intended to boost the domestic rattan furniture industry (Belcher, 2001/2). Due to the recession of the late 1990s, and in response to an International Monetary Fund (IMF) request, the ban was lifted in 1998 and raw rattan cane export flooded back onto the international market (Vantomme, 2003;

Siagian, 2004). Since the withdrawal of the ban, rattan cane export policy has frequently changed. From 2004 onwards a series of regulations were enforced, e.g. an export ban for wild raw rattan cane (Ministry of Industry and Trade, 2004) and an export quota for cultivated rattan canes (Ministry of Trade, 2005).

A decree issued by the Minister of Internal affairs in 2005 suspended the authority of the District Head (*Bupati*) to issue permits for timber and rattan cane extraction (Purwanto, 2008b). In Buton, the District head could only authorise small scale permits for non-commercial extraction of 20 m^3 of timber and 20 ton of rattan per permit. The reality in the field is more complex, with permit holders apparently continuing to exploit rattan or timber, despite the limited allowance (Puwanto, 2008b).

Job alternatives may be the best option to dissuade local people from entering forest and extracting NTFPs such as rattan canes. However, it is essential to find out whether current cane harvesting has been conducted sustainably, with minimum impacts on the forest ecosystem and with sustained standing stocks. This chapter addresses that issue by using available external information and evidence found in the preceding chapters of this thesis. The chapter finishes with discussion of conceptual management options/scenarios with regards to future wild rattan cane harvesting in Lambusango forest.

Four specific objectives have been formulated as follows:

1. To investigate the factors underlying wild rattan cane harvesting and preferences to continue the practice.
2. To assess the effects of dynamic rattan trade regulations and price on the production of rattan canes in Buton and the Lambusango area.
3. To investigate indicators of rattan cane harvesting sustainability, which include resource abundance, evidence of ecological impacts and economic viability.
4. To examine possible rattan cane harvesting scenarios based on local preferences, policies and regulations, development intervention and indicators of harvesting sustainability.

7.2 Methods

The conceptual framework to be followed in this chapter, also based on the results and discussions of the previous topics of this PhD research, is presented in Figure 7.1.

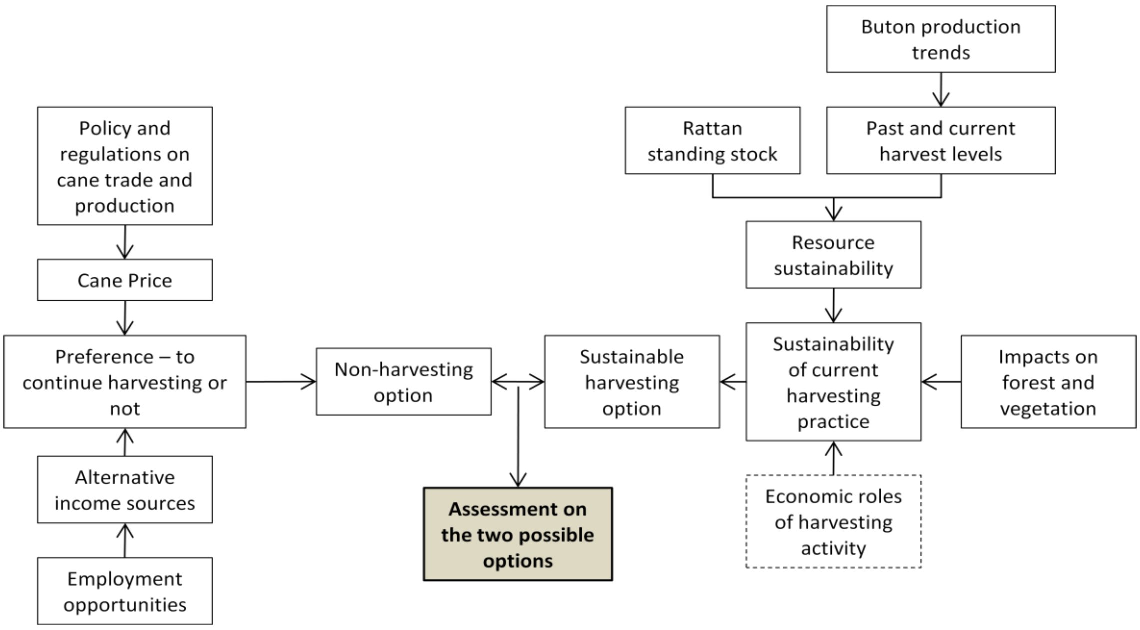


Figure 7.1. Conceptual framework for rattan cane harvesting sustainability assessment

The research starts with the preferences of harvesters. Evidence from external factors including alternative industrial employment is examined in relation to rattan cane production trends. Harvesting sustainability is assessed from the perspectives of resource availability, ecological impacts and economic dependence. Two possible scenarios are then discussed.

7.2.1 Scope of analyses

The analyses and discussions cover different scales ranging from national, Buton district, subdistricts within Buton, village hamlet to forest sites. National and Buton district information gives the broader scale which is assumed to affect trends within the study area, and covers export, trade, production and policies. Trends in cane production levels and available job alternatives are observed at subdistrict scale because data at village level were not available. Examination of harvesting sustainability is conducted at the study area level, using the results for forest and villages/hamlets from the preceding chapters. The villages and their administrative relations with the subdistricts are described in Chapter One, section 1.4.2.2.

7.2.2 Preferences and underlying reasons for harvesting wild rattan cane

Preferences to continue cane harvesting or not and the underlying reasons are taken as the basis for further analyses. The questionnaire survey presented in Chapter Four and Chapter Six included two major umbrella questions to tap harvesters' opinions regarding future harvesting: whether or not harvesters prefer to/will continue harvesting rattan canes in the future and what the main reason is for harvesters wanting to continue rattan cane harvesting (Appendix 7, Section B.5).

7.2.3 Rattan cane price and trade at district and national levels

For Buton district and subdistricts, data was obtained from *Buton dalam angka* (Buton in figures) and *Kecamatan dalam angka* (subdistrict in figures) published by *Biro Pusat Statistik* (Central Bureau of Statistics) or BPS. For Indonesia rattan cane exports, information was gathered from the International Network of Bamboo and Rattan (INBAR). The published INBAR figures used in this study are quantity of exported furniture cane in metric ton and export value in US dollar (INBAR, 2009). Time series data was collected to cover the dynamics of the past 10 years (1997-2007), during which Indonesia's national rattan cane export policy changed in response to various international and domestic situations. Data and information at the village level consisting of cane price, annual harvest level and price of rice, was gathered through the questionnaire survey as well as from village informants.

In national and international markets, the trade includes large diameter canes and more commercially popular species such as *Rotan Manau* (*Calamus manan*) and/or *Rotan Sega* (*Calamus caesius*). For Buton rattan cane production obtained from *Kabupaten Buton Dalam Angka*, the species having major commercial value are *Rotan Batang* (*Calamus zollingeri*) and *Rotan Lambang* (*Calamus ornatus*). The weight of Buton district production is the semi-processed cane weight, which is approximately 40-50% of the freshly harvested cane; and therefore to approximate the semi processed cane weight, harvest weight from Lambusango data is multiplied by 0.45 (Rahim, pers. comm.; La Ete, pers. comm.). Regarding trends at national, district and local scales, the effects of differences in species and diameter classes are assumed to be constant throughout the period of analyses and therefore for trend observation they are assumed to cause negligible biases.

To indicate the true values of the cane price, relative price with rice is used. The relative price is compared to cane production to observe the effects of price on production level. This time series analysis is conducted to observe the dynamics of price and production alongside changes in national as well as district rattan policies. Due to the lack of time series primary data from the study area, the Lambusango harvest levels give one snapshot of the average annual level for 2004-2006. Approximation methods such as ratios and proportions are applied to relate Lambusango trends to district level data.

7.2.4 Industries and job alternatives

Harvesting may be less preferable if there are suitable job alternatives available (Gubbi and MacMillan, 2008). Industrial labour has been considered as alternative opportunities for unskilled work similar to wild rattan cane harvesting. Employment opportunities in the villages are represented by the availability of industries at sub-district (*Kecamatan*) level. Data was obtained from *Kabupaten dalam Angka*. The original data gave the number of industries classified into home industry, small scale industry, medium scale industry and large scale industry and the employment opportunities for each class are 1-4 people, 5-19 people, 20-99 people and ≥100 people respectively (*BPS*, 2006). Here, representative values for each class of home industry, small scale industry and middle-large scale industry are used, namely values of 2, 10, 70 respectively, and the total number of employment opportunities in the respective subdistrict are calculated. Mid-scale and large-scale industry classes are combined because prior to 2000 only data on the combined class is available.

'Labour absorption' is calculated as the proportion of industrial employment opportunities over productive-age population (15-55 years) and the resulting figures are compared to the dynamics of rattan production in the respective sub-district (*Kecamatan*) throughout the period of 2000-2007.

7.2.5 Indicators of harvesting sustainability

To give an indication of current harvesting sustainability in the Lambusango area, two data sources are utilised: annual harvest levels from the villages for 2004-2006 and rattan cane standing stock for forest sites in 2006. Data calculations and results are presented in the preceding chapters.

Research on rattan demography including stem growth rate for major rattan species has been conducted in Lambusango (Powling, pers. comm.). Preliminary results are used in this study, and further work is ongoing to achieve more reliable outputs. It has been determined that *C. zollingeri* growth rates are 1.5 m yr^{-1} for total stem length less than 4 m and 2 m yr^{-1} for total stem length of 4 m or longer, while for *C. ornatus*, the annual growth rate is 1.05 m (Powling, pers. comm.).

The two major species, *Calamus zollingeri* and *Calamus ornatus*, were analysed to represent the overall harvest levels in the Lambusango area. Rattan cane harvest levels for each village/hamlet and rattan harvest zone (RHZ) were discussed in Chapter Four. In this chapter, further calculations and analyses are applied to rattan standing stock in 2006 and are based on the village cane harvest levels. A number of rules and definitions are explained below:

The unit of analysis is Rattan Harvest Zone (RHZ)

To obtain RHZ annual harvest level, the village harvest level is divided by a factor that roughly represents the proportion of the village harvest level over the estimated total RHZ harvest level. Factors are applied as follows:

- 1 if the RHZ is harvested only by harvesters from the surveyed village,
- 0.75 if most harvesters to a RHZ are from the respective village and
- 0.5 if the RHZ is shared between the surveyed village and neighbouring village(s)

To observe the equivalence between RHZ harvest level and harvestable cane standing stock based on the forest inventory, the RHZ harvest level is converted into per ha and eventually per forest sample area.

For Anoa, only four sample plots from the total of seven are considered in the calculation, since only four are located in the Anoa RHZ (see Chapter Five and Figure 5.1).

Harvestable cane is used to represent rattan standing stock. For harvest, the cane average length is 6 m; therefore to get multiple canes, a stem's harvestable length should be a multiple of 6 m. Further definitions used in this study are as follows:

- One harvestable cane = the 6m piece in the stem that can be harvested, e.g. the length for 2 harvestable canes is 12 m
- One harvestable stem = the length of rattan stem in the plant/clump that is harvestable, as in the equation below:

$$L_H = L_T - (L_L + L_U) \quad (7.1)$$

where: L_H= harvestable stem length, L_T= total stem length, L_L= lowest-part stem length, L_U= upper-most stem length.

- For the two commercial species discussed in this chapter, approximations based on local information are applied: for *C. zollingeri*: L_L = 3 m, L_U = 3 m, for *C. ornatus*: L_L= 1 m, L_U = 3 m
- A 1 m cane of *C. zollingeri* weighs 0.84 kg (Gunawan, 2007). For *C. ornatus*, due to the unavailability of measurement data, an estimation was made utilizing volume proportion of *C. zollingeri* and *C. ornatus*. The estimated weight for 1 m of *C. ornatus* is 0.37 kg.

In Buton district, 2005-2006 production is lower than previous years. Village harvest levels obtained in this study are classified as 'low harvest level' (LHL). To estimate village harvest level during peak years, the proportion between high production and low production at Buton district level is used. The estimated harvest level is termed 'high harvest level' (HHL). The data shows that Buton high production was 3 times higher than its lowest production, and therefore for village harvest level: *HHL= 3 * LHL*.

Standing stocks of two consecutive years are estimated, 2007 (T_2) and 2008 (T_3), and for each, two harvest level settings (LHL and HHL) are applied as the bases for estimation. Indication of sustainability is thus observed from the rate of standing stock changes in each harvest level setting. The overall flow of calculations to estimate the annual standing stocks is presented in Figure 7.2.

To determine which canes were harvested at each $T_{(1+n)}$ from the entire stem population in a sample area, one-time random selection is applied.

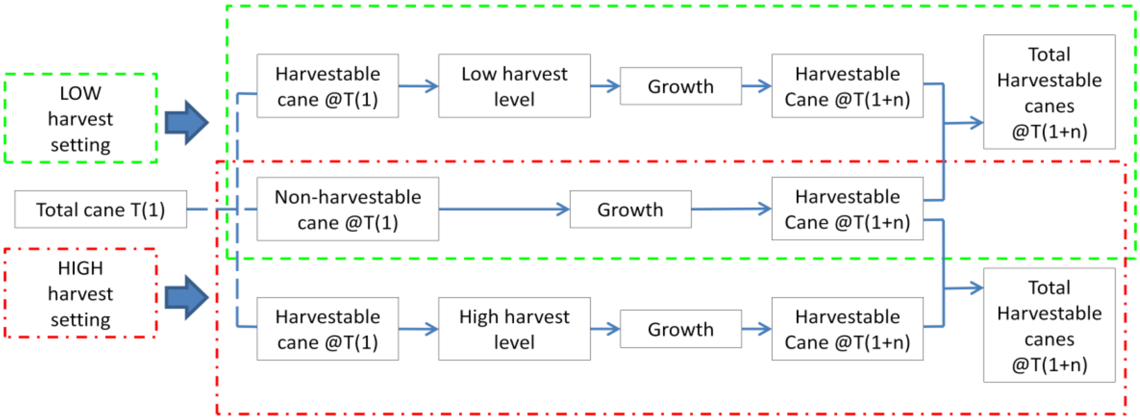


Figure 7.2. Flow chart for standing stock estimation based on LHL and HHL

Cane standing stocks and harvest levels can affect each other, i.e. the availability of harvestable canes may affect the levels of harvest and vice versa. Within the scope of this study, it is not possible to conduct comprehensive observations and conclude which more strongly affects the other. Chapter Three discussed the effects of natural factors on plant/clump abundance, although the effects of such natural factors on the abundance of canes, especially the abundance of mature canes, could not be observed accurately (see Chapter Three, section 3.4.5 for discussion). On the other hand, does harvesting take into account the standing stocks available in the forest? In this chapter, an attempt to observe the relationship is made. Simple scatter plots between standing stocks and harvest levels are made by taking the LHL as an example, and the relationships are observed by also referring to the preceding discussions on the natural factors that might affect cane abundance.

Aside from using quantitative analyses to indicate rattan cane harvesting sustainability in the Lambusango area, the perceptions of harvesters are also considered and descriptive analyses conducted. During the questionnaire survey, questions asked whether harvesters had found rattan cane abundance in the forest to be increasing, constant or decreasing during the recent years of harvesting (2004-2006) (Appendix 7, Section B.7).

7.2.6 Management options for rattan cane harvesting

The underlying reasons and preferences for harvesting are the bases for the subsequent analyses. Indications of harvesting sustainability function as arguments to consider continuing the practice of rattan cane harvesting. Based on these, conceptual management scenarios for wild rattan cane harvesting as a secondary livelihood strategy in Lambusango area are developed and discussions are directed based on the justification, knowledge gaps and potential impacts.

7.3 Results and discussion

7.3.1 Preferences and underlying reasons for harvesting wild rattan cane

One hundred and eleven (111) harvesters took part in the questionnaire survey from seven villages. The majority of harvesters (87%) expressed a preference to continue harvesting, and only 10% responded that they did not want to continue harvesting. Among the 87%, 33% responded that cane harvesting is an important cash income and their second main livelihood activity after farming and would definitely continue harvesting in their off-farm period. 54% of respondents showed an interest in continuing harvesting but put forward conditions under which they would still be interested. The conditions for this latter preference are: the price is good (47%), there is no other income-source option (45%) and rattan is abundant and easy to reach in the forest (8%). Figure 7.3 below illustrates preferences for continued harvesting and the underlying reasons.

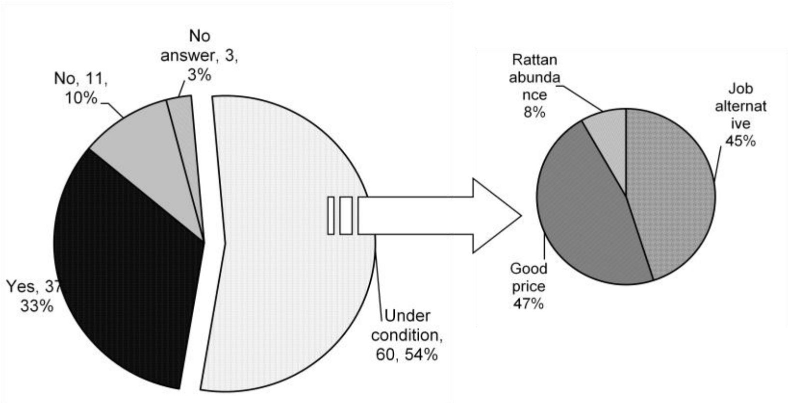
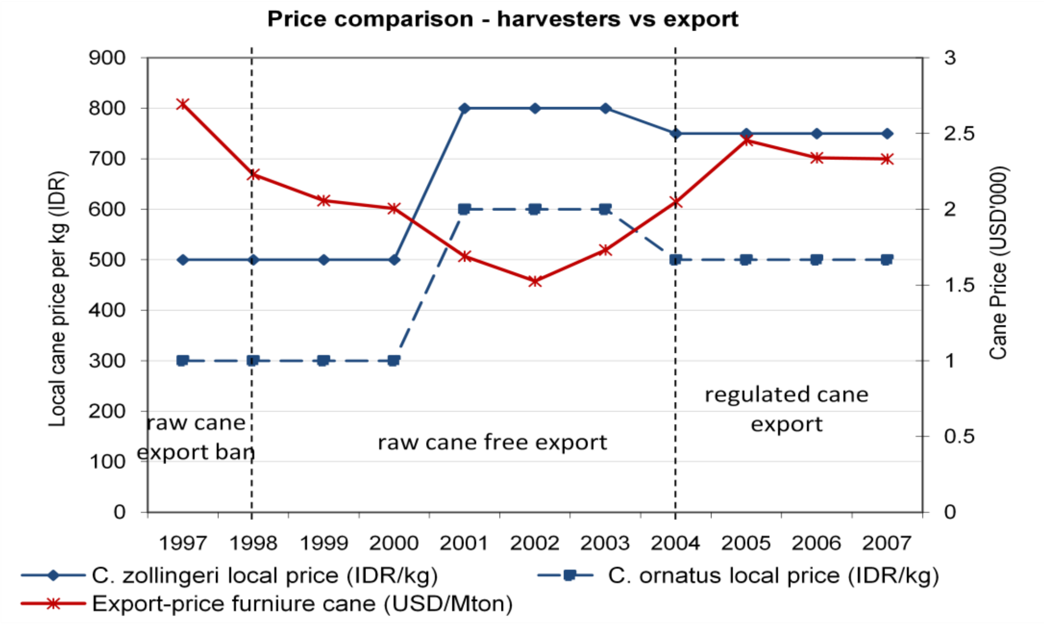


Figure 7.3. Preferences on rattan cane harvesting as an income source

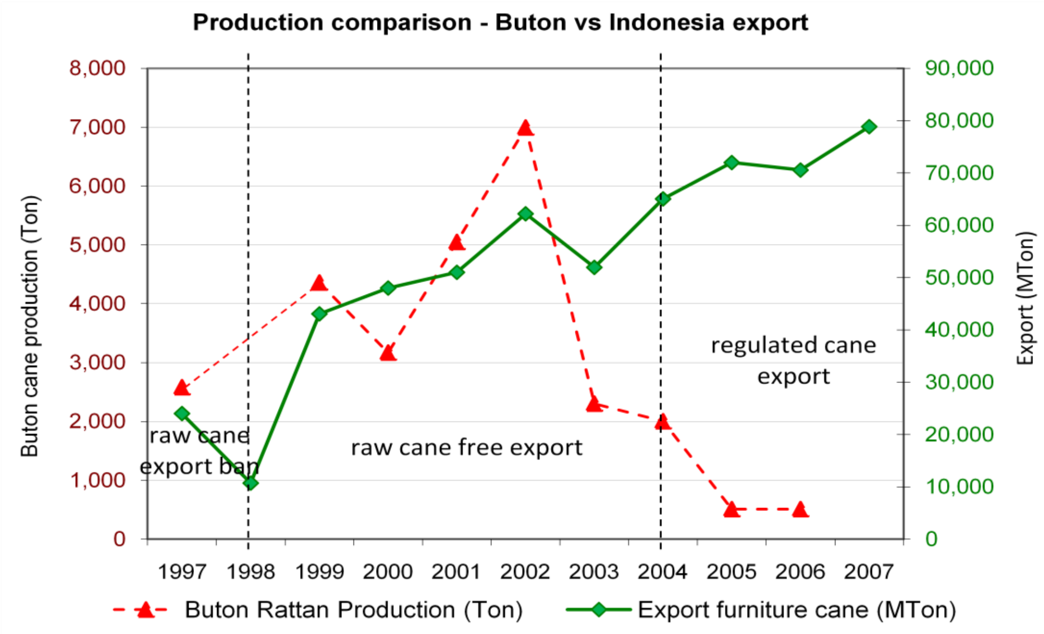
Of those who prefer to stop harvesting if there are other jobs available, most also added that they were aware of their low education and of having no particular skills to offer, and therefore realised the small likelihood of being employed, except as labourers.

7.3.2 Rattan cane price, trade and regulations affecting production

The price of rattan cane per kg harvested at village level was relatively constant from 1997 to 2000, before increasing in 2001 by 60% for *C. zollingeri* and 100% for *C. ornatus*. In subsequent years the price was relatively constant after a slight decrease in 2004 of 6% for *C. zollingeri* and 17% for *C. ornatus* (Figure 7.4 (a)). Furniture cane export price shows a different trend with the price decreasing from 1997 to 2002, from USD 2,700 $Mton^{-1}$ (metric ton) to USD 1,500 $Mton^{-1}$ and increasing from 2002 to 2005 to USD 2,455$Mton^{-1}$, before levelling off at around USD 2,300 $Mton^{-1}$ (Figure 7.4 (a)). After lifting the raw cane export ban in 1998, Indonesia’s export price decreased due to the flooded export market. In contrast, at village level, the price increased in 2001 and did not show significant changes until 2007.



(a)



(b)

Figure 7.4. (a) Cane price trends: export price and Lambusango price; (b) Rattan cane production in Buton and Indonesian export

The quantity of exported cane furniture increased from 1998 to 2007 conforming to the free raw cane export after the ministerial decree in 1998 (Figure 7.4(b)). It continued to increase despite several changes in export policy and regulations starting from 2004. For Buton district, production increased from 1997 to 2002, from 2,580 tons to 6,995 tons and afterwards decreased to 508 ton in 2006. Estimated semi-processed cane production from the study villages shows an average of 490 ton yr^{-1} for 2004-2006.

Relative cane price to rice shows slightly different trends from those of actual rattan cane prices; relative rattan cane price at village level for Lambusango forest continued to decrease from

2002 to 2007, from 0.33 to 0.17 for *C. zollingeri* and from 0.27 to 0.11 for *C. ornatus* (Figure 7.5). The decreasing value of rattan cane is consistent with the trends in cane production, where the peak was in 2002 (6,995 tons) and decreased to 508 tons in 2006.

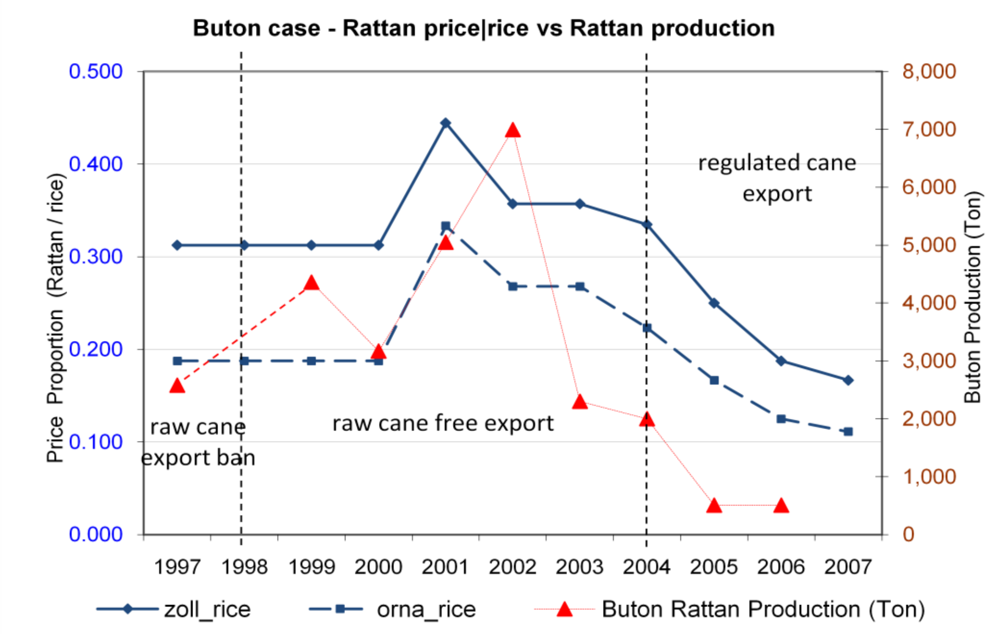


Figure 7.5. Comparison of rattan cane-rice proportion and cane production at Buton district

Rattan cane export price seems responsive to changes in the export policy. After the lifting of the export ban on raw rattan cane in 1998, raw cane production increased resulting in price decreases due to the greater supply. Lambusango villages' price did not follow the export price trends, which is very likely because Buton cane sale has largely been supplying the domestic furniture industry in Java. In response to the unrestricted raw cane export (1998-2004), it was reported that there was a wave of complaints from national furniture industries due to the increase in national cane price and competitition with the export market (Rudijanto, 2004).

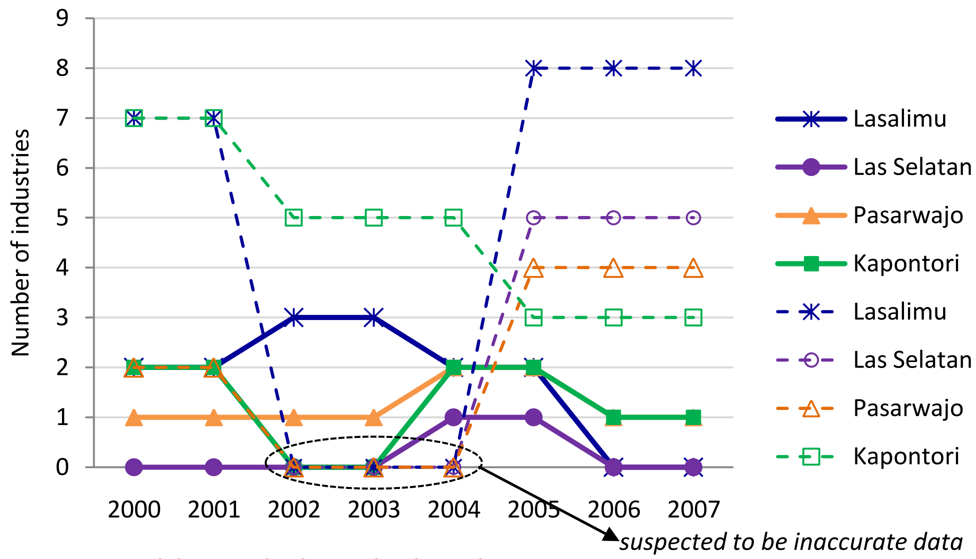
Buton cane production increased after the export ban lifted in 1998 and was highest in 2002. This also seems to be a response to the high price in early 2000 at a local level, which increased the attractiveness of rattan cane harvesting in Buton. The decrease in production in the mid-2000s was a response to the issuance of the new policy in 2004-2005 both at national level and Buton district level (see section 7.1). Estimated semi-processed cane production from the study area for 2004-2006 was 490 ton yr^{-1}, and by observing the production graph in Figure 7.4 (b), similar to the trends in Buton district, this tonnage is assumed to be the lowest tonnage in the study area compared to the preceding years. It is very likely that the highest production in the study area also occurred in 2002 with the production of approximately three times that of 2004-2006, i.e. 1,467 ton.

Buton production trends do not conform to export patterns probably because the entire Buton production was wild forest-based cane which was the main target of the 2004 export ban and the ministerial regulation in 2005 (Ministry of Trade and Industry, 2004 and Ministry of Trade, 2005). Therefore, by regulation, the export market was closed for Buton cane starting from 2004. At the same time, the increase in staple food price, reflected in the decreasing rattan cane price relative to rice price, affected the attractiveness of rattan cane harvesting to the villagers. The opportunity cost of cane harvesting became higher, reflected in the competition with daily labour wages. As return to labour is an important determining factor when job alternatives are available, rattan cane harvesting became less attractive. In villages with heavy past rattan cane harvesting like Wining village, in 2006-2007 there was a wave of temporary out-migration of villagers who used to engage in rattan cane harvesting to Mollucan islands to seek new livelihoods, mainly in trading (Rahim, pers. comm.).

7.3.3 Industrial employment opportunities as job alternatives

Comparison of the number of industries among subdistricts was complicated by the reorganisation of the subdistricts in Buton in 2003 and again in 2007. Data was adjusted to be equivalent with the 2003-2006 situation. Data was incomplete for 2000, 2001, 2004 and 2006 and therefore estimation and approximation were needed.

Only small scale and mid-large scale industries were taken into account in this analysis, because home industries normally only employ family members. Throughout the period of 2000-2007, there were 7-8 small-scale industries found in Lasalimu, 0-5 in Lasalimu Selatan, 2-4 in Pasarwajo and 3-7 in Kapontori (Figure 7.6). For mid-large scale industries the number ranges between 1-2 industries in all the subdistricts throughout 2000-2007, except in Lasalimu where for two years (2002-2003) there were three mid-large scale industries.

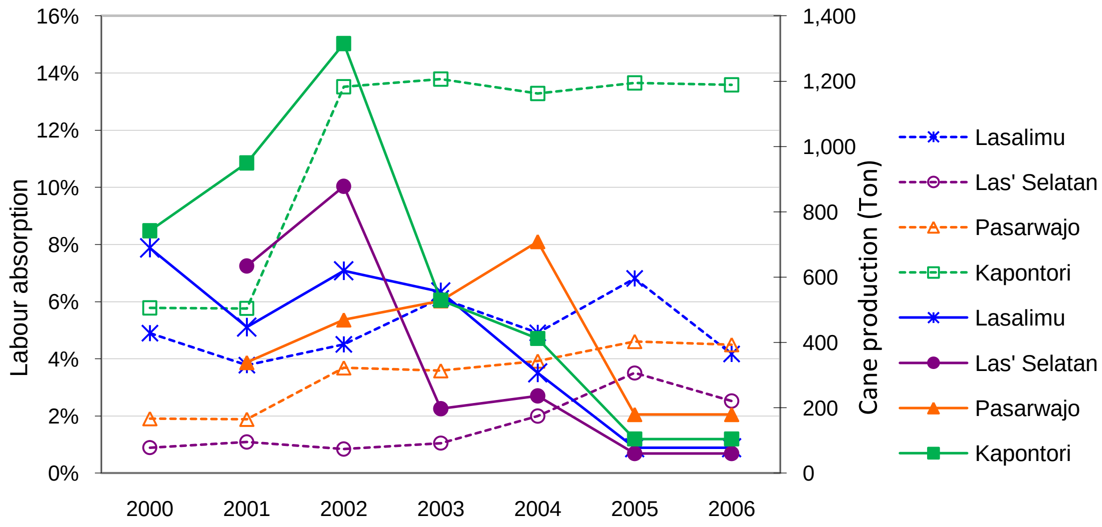


Source: Buton dalam Angka (Buton in Figures) , BPS

Figure 7.6. Trends in number of industries for each subdistrict, 2000-2007. *(solid line= mid-large scale industries, dashed-line=small scale industries)*

Throughout the observation period, labour absorption was found to be lowest in Lasalimu Selatan, which ranged from 0.8% to 3.5% of the working age population and highest in Kapontori which ranged from 5.8% to 13.8% (Figure 7.7).

The peak rattan production year was 2000 for Lasalimu (689 tons), and afterwards there were slight decreases and increases until 2006. The highest peak occurred in 2002 for two districts, Kapontori and Lasalimu Selatan, with production of 1,315 tons and 878 tons respectively. After that peak year, rattan production kept decreasing until 2006, to 104 tons for Kapontori and 60 tons for Lasalimu Selatan. For Pasarwajo, the peak came later in 2004 (709 tons), and after a drop in 2005, the production remained constant at 180 tons. Unlike industry and employment opportunities data, rattan cane production data was available only until 2006.



Source: Buton dalam Angka (Buton in Figures), BPS

Figure 7.7. Comparison of trends between labour absorption and rattan cane production 2000-2006 per subdistrict *(solid line = cane production, dashed line= labour absorption)*

Rattan cane production tends to decrease over time, while industrial employment opportunities have slowly increased. These opposing trends can explain the influence of industrial labour as a disincentive to rattan harvesting, and as an activity which gives daily returns comparable to rattan cane sale but with less laborious work. However, the results were not consistent for all the subdistricts. The decreasing cane production in Kapontori subdistrict is likely to be also due to the rapid development of the subdistrict into a peri-urban area being a subdistrict close to and with good access to the district capital. In Wining village, with the reopening of the asphalt mine, several villagers who used to harvest rattan canes specifically mentioned their preference to work as asphalt labourers rather than rattan cane harvesting. Some harvesters, however, revealed that daily return to labour was still the most important consideration, so that if rattan cane price increases, harvesting would become more attractive than the labour.

7.3.4 Rattan cane standing stocks and harvest levels

7.3.4.1 Results of cane standing stocks and harvest levels

Results from the rattan inventory conducted in 2006 provided the main information for calculating rattan cane standing stock in RHZs. The results for each species are shown in Table 7.1 below.

For *C. zollingeri*, the highest harvestable standing stock for 2006 was in Wahalaka with 260 canes ha^{-1} equivalent to 1,310 kg ha^{-1} and the lowest was in Wabalamba with 16 canes ha^{-1} equivalent to 78 kg ha^{-1}. For *C. ornatus*, the highest was in Bala with 343 canes ha^{-1}, equivalent to 760 kg ha^{-1} and the lowest was in Lasolo, 110 canes ha^{-1} or equivalent to 244 kg ha^{-1}.

Table 7.1. Rattan cane standing stocks in each RHZ based on 2006 survey

RHZ	Sample area (m2)	*C. zollingeri*			*C. ornatus*		
		Harvestable canes per sample area	Harvestable canes ha^{-1}	Harvestable canes (kg ha^{-1})	Harvestable canes per sample area	Harvestable canes ha^{-1}	Harvestable canes (kg ha^{-1})
Anoa	2000	5	25	126	33	165	366
Bala	4000	9	23	113	137	343	760
Lapago	3500	17	49	245	58	166	368
Lasolo	2000	7	35	176	22	110	244
Wabalamba	4500	7	16	78	51	113	252
Wahalaka	4500	117	260	1,310	126	280	622

The resulting annual LHLs and HHLs for each species and site are presented in Table 7.2 below. For *C. zollingeri*, under the LHL, the highest harvest level was in Wahalaka (27 canes ha^{-1} yr^{-1}) and the lowest level in Wabalamba (5 canes ha^{-1} yr^{-1}). For *C. ornatus*, the highest harvest level was also in Wahalaka (19 canes ha^{-1} yr^{-1}) and the lowest harvest level was in Anoa (2 canes ha^{-1} yr^{-1}). Harvest level under HHL is approximately three times higher than LHL (see section 7.2.5) and the pattern among sites is thus similar to that of LHL.

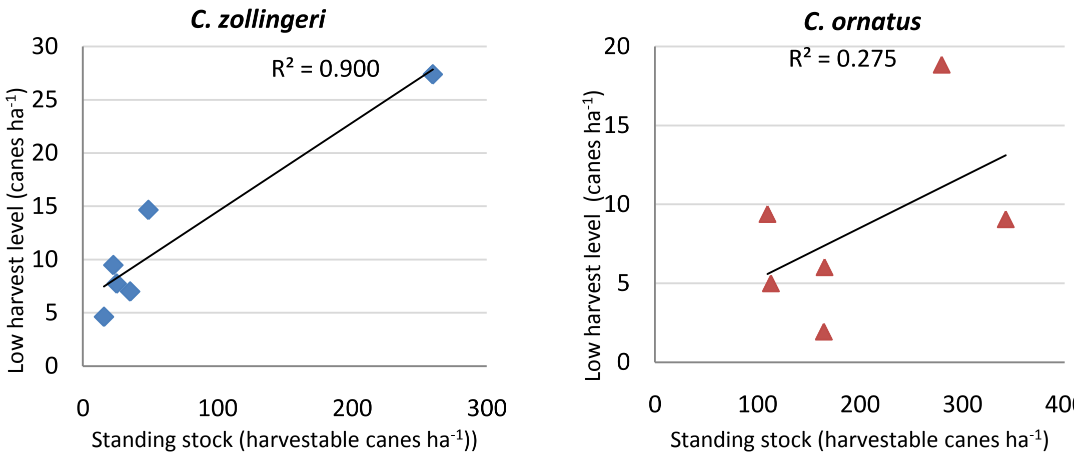
Table 7.2. Cane harvest levels/production levels for LHL and HHL

RHZ	*C. zollingeri*		*C. ornatus*	
	LHL (canes ha^{-1} yr^{-1})	HHL (canes ha^{-1} yr^{-1})	LHL (canes ha^{-1} yr^{-1})	HHL (canes ha^{-1} yr^{-1})
Anoa	8	24	2	6
Bala	9	29	9	28
Lapago	15	45	6	18
Lasolo	7	22	9	29
Wabalamba	5	14	5	15
Wahalaka	27	83	19	57

7.3.4.2 Relationships between harvest levels and cane standing stocks

There is evidence that Wahalaka has much higher harvest levels and standing stocks than other RHZs, while the site with the lowest harvest level and standing stock is Wabalamba. A scatter plot of standing stocks against harvest levels (Figure 7.8(a)) shows a strong positive linear relationship (R^2=0.90) for *C. zollingeri*.

Different patterns occur for *C. ornatus*, the highest harvest level is also in Wahalaka, while its standing stock was the second highest. Anoa has the lowest harvest level for *C. ornatus*, and the standing stock is moderately high. Figure 7.8(b) shows that the positive relationship between standing stocks and harvest levels is much weaker (R^2=0.275), which indicates that there are other factors that affect harvest level and standing stock variations for *C. ornatus*.



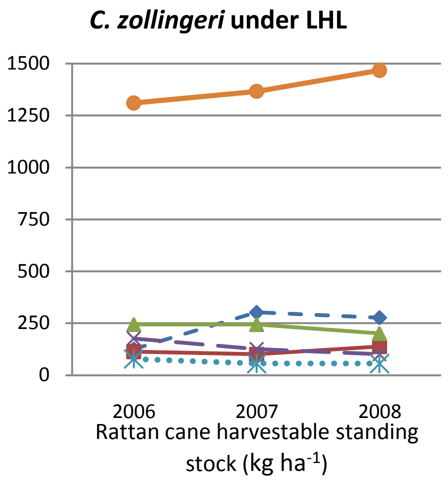
(a) (b)

Figure 7.8. Relationships between standing stock and harvest level/production (a) for *C. zollingeri* and (b) for *C. ornatus* (each point in the graph represents a site)

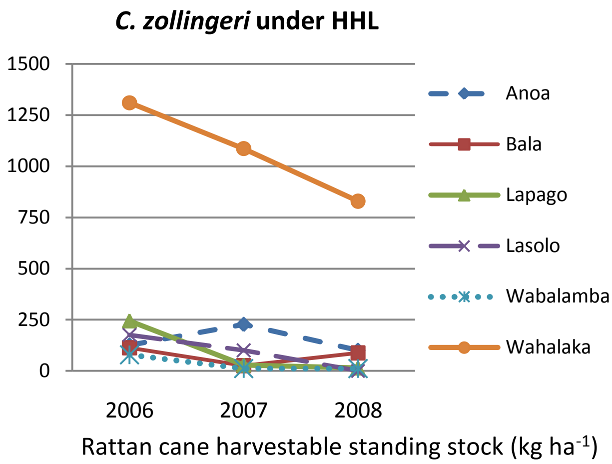
For *C. zollingeri*, harvest level is strongly correlated with standing stocks, very likely because as the most commercially valuable species, harvesting tends to optimize or even maximise the available stocks. The different pattern for *C. ornatus* could be due to its low commercial value. Low price at times combined with low demand by the traders, creates disincentives to harvest this species. In RHZs where accessibility is low and difficult terrain dominates, such as Anoa, *C. ornatus* harvesting costs are higher and therefore, low-price canes like *C. ornatus* are not attractive to the harvesters. High standing stock might occur due to the favourable natural conditions, but that is not necessarily associated with high harvesting, due to its low commercial value. As previously discussed, acidic soil, which is dominant in Bala, plays a role in the abundance of *C. ornatus* (see Chapter Three, section 3.4.3), which most likely also affects the abundance and growth of the canes. The combined soil factor and moderate harvest level result in high abundance of *C. ornatus* standing stock, the highest among all sites.

7.3.4.3 Standing stock trends in 2006-2008: the case of C. Zollingeri

Based on two harvest level settings (LHL and HHL), potential standing stocks in each RHZ estimated for 2007 and 2008 are presented in Figure 7.9(a). For the *C. zollingeri* LHL setting, the standing stocks are relatively stable for most RHZs except Anoa which experiences a large increase (140%) for 2006-2007. There are small decreases in Lapago, Lasolo and Wabalamba and a slight increase in Wahalaka for 2007-2008; all with small percentages (≤30%). For the HHL setting, most RHZs show persistent decreases from 2006-2008 (Wahalaka, Lasolo, Lapago and Wabalamba), with the largest decrease occurring in Wahalaka for 2007-2008 (24%). Bala and Anoa show a combination of increasing and decreasing standing stocks, with Anoa showing increase in 2006-2007 and decrease in 2007-2008, and Bala the reverse.



(a)



(b)

Figure 7.9. Rattan cane standing stock estimates for *C. zollingeri* in 2006-2008; (a) for LHL and (b) HHL

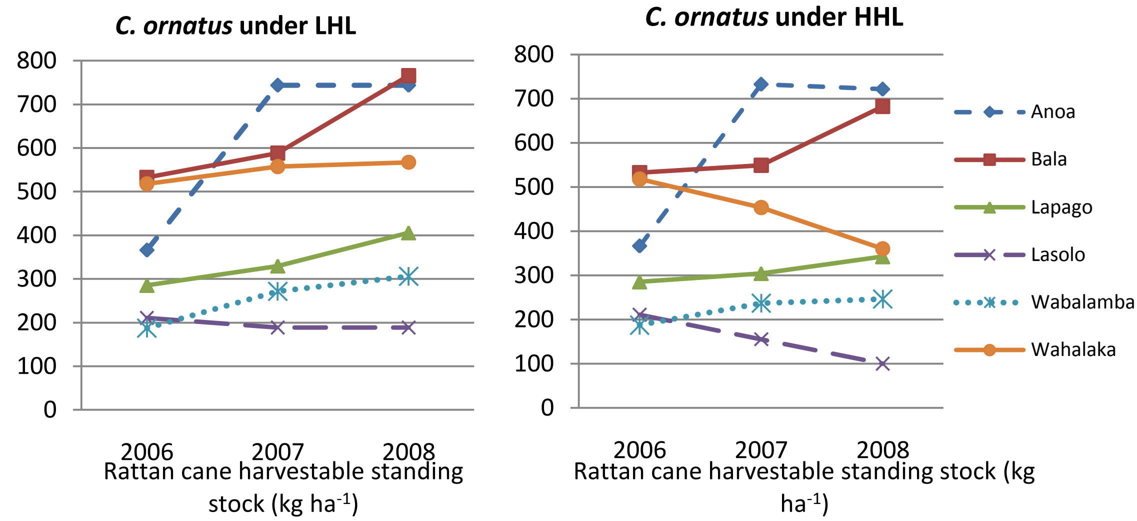
Based on the two periods of observation, the *C. zollingeri* LHL setting shows evidence of constant abundance of harvestable stems. Regeneration is assured and number of harvestable canes is sustained; the favoured situation for resource sustainability. The *C. zollingeri* HHL setting indicates that the number of harvestable canes decreases drastically and overharvesting occurs for areas with very low abundance of harvestable canes and low number of regenerating stems. Some sites with low standing stocks in the beginning year, even under the HHL setting, show a slight increase in harvestable stems for one of the two periods. Wahalaka, which has much higher standing stock, surprisingly experiences constant decreases in the two observation periods under the HHL setting. This shows that young stems and newly-sprouting shoots can be essential factors.

Athough this study does not aim to simulate the potential harvestable stems in the long run, by observing the estimated trends for 2006-2008, it is likely that a low harvest level strategy can ensure a stable or increasing number of harvestable canes of *C. zollingeri* in the long run. Applying HHL in the long run may lead to resource scarcity or depletion. Observing that in some sites the number of harvestable stems increases for one of the two observation periods, it is possible that a high level of harvesting for *C. zollingeri* may be sustainably applied within a more stringent rotation system.

A study of wild rattan in Lore Lindu National Park, Sulawesi found that the sustained harvest yield of *C. zollingeri* is between 56 m ha^{-1} yr^{-1} and 101 m ha^{-1} yr^{-1} of cane length (Siebert, 2004). It is not clear whether those are harvest cane length or harvest stem length, but by roughly converting the lengths into number of canes, the figures can be translated into 8-9 canes ha^{-1} yr^{-1} and 16-17 canes ha^{-1} yr^{-1}. These figures are equivalent to the current annual harvest levels of most Lambusango sites, or in another words, with the low harvesting level setting, except for Wahalaka (see Table 7.2).

7.3.4.4 Standing stock trends in 2006-2008: the case of C. ornatus

Rates of changes in standing stock for *C. ornatus* under the LHL setting can be seen in Figure 7.10(a). Four sites show increases from 2006 to 2008, Bala, Lapago, Wahalaka, Wabalamba, but with different rates ranging from 2% to 45%. Anoa with almost zero harvest quantity shows a sharp increase in 2006-2007 and is constant in 2007-2008. Only Lasolo experiences a slight decrease in 2006-2007 (11%) before staying constant in 2007-2008. Under the HHL setting (Figure 7.10 (b)), Bala, Lapago and Wabalamba show increases similar to those under the LHL setting, with lower rates for each site, ranging between 3% and 26%. Wahalaka shows decreases, in contrast to its trends under the LHL setting, as does Lasolo, with rates between 12% and 36%. Anoa experiences similar trends to the LHL setting with a sharp increase in the first period followed by relatively constant stocks in the subsequent period.



(a) (b)

Figure 7.10. Rattan cane standing stock estimates for *C. ornatus* in 2006-2008; (a) for LHL and (b) HHL

For *C. ornatus*, a low harvesting level seems to assure sustained standing stocks and brings increases in some sites, mostly in the second observation period, owing to the regeneration of young stems. The high harvest level seems to allow sustained standing stocks in some sites, while in others decreases take place.

For longer term estimation, with consideration of regeneration processes, the LHL harvesting strategy for *C. ornatus* will most likely increase standing stocks in most of the sites, and it is likely that sustained harvestable stems will not be of concern. The HHL strategy in the two observation periods results in more positive trends compared to those of *C. zollingeri*, due to the higher actual number of *C. ornatus* harvestable stems in most sites. However, for a longer term HHL strategy, the slower growth rate of *C. ornatus* stem compared to that of *C. zollingeri* (see section 7.2.5) may slow down the regeneration process. Therefore, overharvesting might still take place unless careful rotation systems are applied.

Because *C. ornatus* has smaller diameter and lower weight, the same harvest weight requires a higher number of canes compared to *C. zollingeri*. Hence a similar harvest weight for *C. ornatus* implies a higher risk for the standing stock abundance and is worsened by the slower growth rate. Lower per kg price of *C. ornatus* has made this species less attractive and thus less harvested, which has been a favourable condition from a resource sustainability perspective.

7.3.5 Perceptions of rattan abundance in the forest

Based on the questionnaire survey, the highest percentage of harvesters (47%) responded that rattan in the forest has decreased in recent years, while 24% said that rattan is becoming more abundant, and 20% said it was constant (Figure 7.11). Most harvesters who claimed that rattan abundance had decreased blamed the higher number of harvesters and based their answers on the increasing distance to harvest mature rattan canes. Those who responded that rattan abundance increased or stayed constant mostly based their answers on their local knowledge that rattan regeneration was taking place.

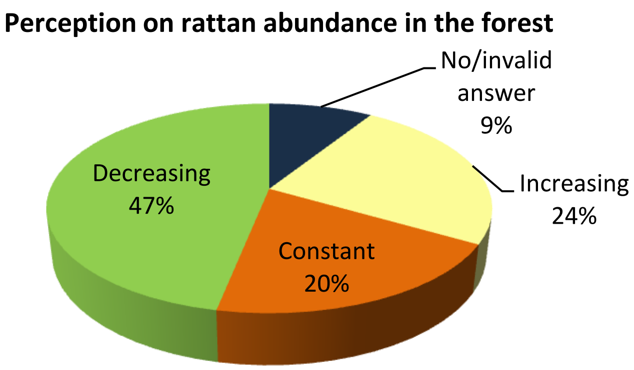


Figure 7.11. Proportion of harvesters' perceptions on rattan cane abundance in the forest

Harvesters' perceptions of the abundance of harvestable canes in the forest also reflect the possible sustained abundance of the resources. The number of respondents having the perception of sustainable resources is equal to the number suspecting that the resource is depleting. Those who perceived that the resource is sustained based their perception on the sprouting of cane shoots and therefore if reproduction processes are not disturbed, resource abundance can be maintained. Common suggestions by harvesters to ensure that regeneration takes place were, among others, rotation systems, which they expressed as 'leaving the area of clumps untouched and returning there when there are enough mature stems to be harvested' and by letting ripe rattan seeds germinate around the clumps/plants.

7.4 Overall discussion of harvesting sustainability

7.4.1 Indicators of harvesting sustainability

Based on the estimations made for commercial species, the ecological sustainability of rattan cane harvesting can be ensured by applying a low harvest level. Rotation systems both in time and place are crucial. Geographic rotations take into account favourable or unfavourable natural settings affecting the abundance of a particular species, while time rotation considers the botanical characteristics of the resources that affect abundance, e.g. cane growth rates of a particular species.

Given that standing stocks can be sustained, other measures of sustainable NTFP extraction such as minimum impacts on forest structure and economic viability of the practice need to be taken into account. Impacts of cane harvesting on trees and other vegetation were discussed in the preceding chapters. Based on the evidence found, rattan cane harvesting caused significant impacts on the regeneration stages of trees, due to habitat sharing with other understorey vegetation, and the vegetation clearing by harvesters (see Chapter Five, section 5.4.2.3). Impacts of harvesting on mature tree stems are considered non-significant due to the limited evidence found. Overall impacts of rattan cane harvesting on forest structure can be considered minimum, although impacts on understorey vegetation should be recognized. Reduced-impact harvesting might need to be considered for even lower impacts on the forest ecosystem.

The economic viability of cane harvesting can be represented by harvesters' dependence on income from cane harvesting and the profitability of the activity. Economic dependence on rattan cane harvesting in the Lambusango area is varied. Approximately 50% of the surveyed villages are considered rattan dependent by having ≥ 50% income from rattan cane harvesting, while the other 50% are less dependent (see Chapter Six). Daily return as the main measure of profitability shows that commercial value or price is the main overall factor. Due to a similar price across Lambusango, variations are determined by amount of effort dedicated to harvesting. Harvesters from villages with the highest time spent in the forest by river-rafting harvesting proved to earn the highest daily return compared to those from villages with daily-trip harvesting. Comparative profitability shown by comparing cane harvesting daily return with local daily wage shows that on average, harvesters from most study villages earn a higher daily return than local daily wages (see chapter 6 for details). Local daily wages in the Lambusango area for 2005-2007 ranged from IDR 25,000 for monthly-hired labour such as at the asphalt mine to IDR 35,000 for daily-hired labour in farming and construction. Cane harvesting daily return ranged from IDR 31,000 to IDR 58,000 (Chapter Six, section 6.3.3).

7.4.2 Limitations of this research and concerns for sustainability arguments

It has been noted that, regarding cane harvesting impacts on habitat, more measures are needed to test the effects on other biological functions in the forest ecosystem including the wildlife populations (see Summary and conclusion of Chapter Five). Other impacts may emerge as chain effects from rattan cane harvesting. Villagers' activities in the forest that are related to livelihood importance are commonly specialised. Anecdotal evidence shows that in harvesting trips, harvesters are not equipped for other extraction activities, nor do they have time to engage in other extractions in between harvesting rattan canes due to the target weight to be fulfilled. However, indirect influences of rattan cane harvesting might occur, increasing more harmful forest extractions, possibly due to the accessibility provided by rattan cane paths and/or familiarity and knowledge of harvesters of forest areas and resources.

It is realised that primary data and methods for the sustainability assessment are fairly limited. Growth rate data was preliminary (Powling, pers.comm.), harvest levels are the result of approximation from annual harvest quantity and standing stock was based on simple calculations. Due to those limitations, estimations of standing stocks were conducted only in two observation periods. Longer term predictions would need better data, e.g. reproductive and mortality data, and methods. However, for indications of resource sustainability within this PhD study, the two-period observations using available data combined with secondary information are considered sufficient to contribute to the overall discussion and for developing conceptual scenarios as presented and discussed below.

7.4.3 Wild rattan cane harvesting towards sustainable forest management

Rattan cane harvesting has been conducted by local people as an alternative income to supplement their main agricultural activities. Despite its seasonal and temporary nature, the pressures of market and policy factors can still lead to various adverse impacts and questioning whether it should be continued or not.

Harvesting permits are given to companies proposing concessions, each of which is given a particular harvesting area, allowable harvest quantity and duration of permits. Based on the permit running in certain villages, local villagers 'register' with middlemen and become harvest labourers who sell the harvest to the middlemen. Despite the seemingly straightforward implementations, in practice, violations occur, most importantly trespassing into conservation zones by harvesters. This has become the greatest concern, but is rather expected primarily due to, among others, resource abundance (see Chapter Four section 4.4.3). Although the procedures may have been originally designed to support sustainability, lack of reliable resource assessment and monitoring and disharmony between various parties in the field have long been leading away from the sustainability ideas.

7.4.3.1 Two possible scenarios

Based on a number of assessments and indications resulting from this study, two basic conceptual scenarios are discussed in this section in relation to rattan cane harvesting as a livelihood strategy: 'Sustainable harvesting' and 'non-forest-based livelihood' strategies.

'Sustainable Harvesting' serves as a resource-based, livelihood-oriented and habitat-friendly cane harvesting option. It should be noted that the main assumptions behind this scenario are: first, harvesting is a secondary seasonal livelihood activity, and second, various local conditions remain as *ceteris paribus*.

This scenario can be justified by three factors, namely high abundance of commercially valuable wild rattan canes - including within the current conservation forest area, rattan cane sale being an important cash source for local livelihoods having been conducted for decades, and indications of sustainable practice found in this study.

Based on the assumptions and justifications above, a number of suggested actions which are required to ensure sustainability are laid out below:

Review and adjustment of conservation zones and forest regulations - Boundary trespassing occurs because rattan resources are abundant in the conservation area (Lambusango wildlife reserve) and terrain and accessibility are favourable for conducting harvesting (see Chapter Four for details). Conflicting interests between favourable circumstances for resource extraction and the importance of biodiversity preservation require careful studies and investigations specific to the local Lambusango context to determine what should be prohibited and what should be allowed. These may or may not lead to adjustments of conservation regulations and/or the boundaries.

For harvesting in the Production Forest zone, better management strategies should be implemented. The possibility of applying for the Village Forest scheme to establish rattan cultivation and/or a rattan agroforestry system is worth exploring (see section 8.2.3.1)

Thorough resource assessments and monitoring - Comprehensive assessments of the standing stock status should be undertaken and updated regularly by local authorities along with improved understanding of the biological characteristics of the commercially valuable species. These will serve as a proper foundation for setting up harvesting strategies and quotas.

Understanding of ecological sustainability by local harvesters - Comprehensive understanding by local harvesters of ecological sustainability of rattan cane harvesting both on rattan resources and on environmental impacts needs to be ensured. Involvement of harvesters in overall harvesting strategies is crucial and can involve participation in resource monitoring and rotation systems.

Improved harvesting techniques - Harvesting techniques may be improved to reduce impacts primarily on other vegetation, on rattan regeneration and on other components of the ecosystem.

As opposed to the sustainable harvesting option above, a ***'non-forest-based livelihood'*** scenario is discussed below. This scenario involves two objectives: first, Lambusango villagers are directed away from forest-based livelihood options towards agricultural and peri-urban livelihoods; second, Lambusango forest is directed to be a full-fledged forest biological conservation area. This scenario primarily implies a minimum harvesting quota under small-scale and non-commercial schemes suppressing forest extraction to the minimum level or down to no-forest-extraction.

A number of potential risks, impacts and considerations related to the forest that arise from this option are discussed briefly below:

Illegal practice - Illegal harvesting is very likely to happen when there are strong market opportunities, e.g. a high price for rattan canes.

Land conversion pressure at the forest edges - Due to potential agricultural land expansion, encroachments into forest edge areas might occur. This issue has long been the main reason of NTFP extraction promotion, i.e. reducing conversion to agricultural lands (see Chapter One, section 1.1.2.2). Various other adverse effects from agricultural intensification, such as erosion and pollution might follow as a consequence of more intensive agriculture.

Voluntary versus involuntary approach - This scenario can imply denying local people's connection to the forest which has provided them with valuable livelihood resources since long before the establishment of the forest reserve. However, voluntary preference by the harvesters to gradually leave wild rattan cane harvesting, assisted by village development interventions, could eventually lead them away from forest-dependent livelihoods. On the other hand, external and involuntary force without prior thorough and justified grounds will likely bring social problems and may lead to social injustice.

Rattan agroforestry and/or rattan cultivation - One approach that could be implemented is the promotion of a rattan agroforestry system, which, if preferred by the harvesters, might serve to gradually reduce their dependence on wild rattan, and to reduce the pressure on the conservation forest. Various considerations should be taken into account, including local preferences for species grown on private farmland, species selection for combining trees with other crops and profitability of cultivation in comparison to wild harvesting (e.g. in Leakey *et al.*, 2005; Roshetko *et al*., 2009). Therefore, careful assessments are needed if this system is to be recommended to the harvesters.

The possibility of rattan cultivation/agroforestry in the Production Forest zone which acts as a forest 'buffer zone' could be a compromise option (see the possibility of Village Forest in section 8.2.3.1).

7.5 Summary and conclusion

Cane harvesters in Lambusango forest show preferences for other income sources. However, profitability of any income source is still the major reason behind choices, and therefore for rattan cane harvesting, the sale price is an important factor in deciding whether they will persist with cane harvesting or change to a different alternative income. Price trends and pertinent regulations were observed to find evidence of the interrelationships between various external factors and rattan cane production in Buton and in Lambusango in particular. The findings show that national and sub-national policies which affect demand and price, influence cane production. The decreasing relative price to rice in recent years also created disincentives for cane harvesting. Evidence from alternative income sources such as industrial labour absorption was also observed. Despite the limitations of the data, there was a pattern of increasing labour absorption in most of the subdistricts in line with decreasing cane production levels.

Resource sustainability was assessed for the two most commercial rattan species, *C. zollingeri* and *C. ornatus*. Two settings of low harvest level and high harvest level were applied to estimate the harvestable standing stocks in the forest. The result shows that a low level of harvesting maintains sustainable harvestable cane abundance. Of the two species, *C. ornatus* has lower harvest levels compared to *C. zollingeri*, due to its lower commercial value, and therefore more easily sustained harvestable canes. The majority of harvesters perceive that rattan cane abundance is constant or increasing in the forest. Regarding other aspects of sustainability, impacts on forest and vegetation structure are considered minimum and profitability of cane harvesting is better than daily wages from other labour available in the villages.

The economic viability of rattan canes involves ecological and botanical characteristics of the species having high commercial values. Characteristics such as clustering rattan and fast growth rate are among those which will support the economic viability of cane harvesting as well as resource sustainability; therefore, the discussions on both issues have become inseparable.

Two conceptual scenarios are discussed: sustainable harvesting and non-forest-based livelihoods. Sustainable harvesting is discussed under the assumptions of rattan cane harvesting being a secondary livelihood strategy and the other circumstances being *ceteris paribus*. A number of suggested actions to ensure sustainability include review and adjustments of conservation zones and regulation, thorough resource assessments and monitoring, understanding of ecological sustainability by local harvesters and improved harvesting techniques. The non-forest-based livelihood scenario is based on two objectives: the villagers are directed away from forest-based livelihood options towards agricultural and peri-urban livelihoods and the forest is directed to be a fully-fledged forest biological conservation area. Two potential risks to the forest that might emerge from this option are the potential for illegal practices and land conversion pressures at the forest edges. Further consideration of this scenario is suggested, including potential for the development of rattan agroforestry in the forest ‘buffer zone’. It can be applied as an effective approach to gradually reduce harvesting in the core forest area and/or conservation forest areas. A gradual and voluntary approach is crucial for fairness and justice in dealing with villagers that have been dependent on the neighbouring forest for generations.

Chapter 8. Summary, conclusion and further reflections

8.1 Summaries and conclusions of key findings

8.1.1 Land cover change and forest degradation

Investigation of forest product extraction and its impacts on forest characteristics began with assessment of landscape dynamics in the study area during the 1991-2006 period using satellite imagery. As well as land use/cover changes, forest degradation was also analysed. Conversion of forest to other land cover types as well as conversion between non-forest types has taken place in Lambusango and the surrounding landscape illustrating the dynamic nature of the study area. Forest loss to agricultural uses has mostly taken place in the Production Forest zone, indicating that conversion was more from secondary forest than the near-primary forest of the core area. The core forest area, Lambusango Wildlife Reserve, shows much less change than other zones and there has been some regeneration of forest.

Tree above-ground biomass (AGB) and its relationship with satellite imagery attributes were studied. There is wide variation in tree AGB, but most of the study area shows levels of woody biomass within the common range of tropical forests in Indonesia and Southeast Asia. The relationship between tree AGB in the forest and attributes derived from satellite images is asymptotic; hence the variation in woody biomass, especially at the higher end, cannot be explained by remotely sensed information. It is concluded that for dense forest such as Lambusango, landscape biomass estimation is not possible using medium resolution and multispectral satellite imagery such as LANDSAT Thematic Mapper.

8.1.2 Rattan species abundance and distribution and the natural factors

One aim of this study is to describe the distribution of common and commercial species of rattan across the Lambusango area and to explain the differences in abundance and diversity with respect to soil and environmental factors.

Seventeen species of rattan had been identified in the Lambusango area (Powling, 2009) and across the six study sites, two dominant species were found: *C. zollingeri* and *C. ornatus*. These are the most commercially valuable species for large and medium diameter canes respectively. Previous studies have found that many rattan species are tolerant of a wide range of altitudes, slopes and light environments. In this study, it was concluded that variations in slope and light regime do not show significant effects on rattan species abundance or diversity. However, there are indications that rattan seedlings are more abundant in moderately shaded environments compared to the extremes of closed or open canopies. No significant association was found between variations in tree and vegetation structure and variations in rattan abundance and presence. There is some evidence of the effects of soil chemical properties; it was found that *C. ornatus* is more abundant on acidic soils.

The effects of natural factors on rattan cane abundance could not be accurately assessed due to harvesting that affects the number of canes present. Similar considerations apply to investigation of the abundance and distribution of solitary or single-stem rattans due to the death of the plant when the cane is harvested. Such analyses could only be accurately conducted by applying sampling methods that control for the effect of cane harvesting. However such methods could not be applied in this study because of various limitations in the field.

8.1.3 Rattan cane harvest levels and accessibility factors

Chapter Four starts to address cane harvesting conducted by local villagers. The major variable being assessed is harvest quantity or harvest level. Harvest levels were assessed against immediate physical and natural factors in the forest, i.e. topographic and accessibility conditions. Conservation designation in parts of the forest could also reduce harvest levels.

Boundaries of rattan harvesting zones have been derived from participatory mapping, but should be considered as an approximation of the areas where harvesters go. PM/PGIS is an effective tool to obtain data and information regarding natural resource utilisation by local people.

This study has found evidence that natural factors such as terrain and accessibility influence the amount harvested. This is not surprising since wild rattan harvesting is conducted individually and involves hard manual labour. However, the accessibility factor is less influential where the resource is abundant. The forestry laws enforced through the designated forest zone system (*kawasan hutan*) do not significantly affect levels of harvesting. In Lambusango, where forest product extraction is a long-standing and common activity, forest designations do not seem to constrain the movements of rattan harvesters. In addition, there is evidence of reluctance to recognise the relatively new conservation forest regulations.

8.1.4 Impacts of harvesting on forest trees and understorey vegetation

After assessing the effect of accessibility and conservation designation on the harvest level, Chapter Five focused on the impacts of cane harvesting on the forest environment. The main focus of this chapter is on forest trees and understorey vegetation. The natural factors which may affect vegetation structure and diversity, consisting of topographical factors and soil chemical properties, were examined. Assessment of the impacts of rattan cane harvesting on structure and diversity also took into consideration timber extraction that occurs to a lesser extent in the study area.

It was found that tree species richness and diversity are affected primarily by topographical factors: slope and altitude, and not by the soil chemical factors tested in this study. However, the woody biomass and size of trees are shown to be slightly affected by soil factors with indications of pH and base saturations having positive effects on tree dbh and tree above-ground biomass.

Previous assessments of the ecological impacts of rattan cane harvesting have reported various results, from direct tree-cutting to the use of tree logs for cane transport. In this study, only small variations in forest structure measures can be attributed to the impacts of rattan cane harvesting. Adverse effects on understorey vegetation density including tree saplings and seedlings are found to be stronger. This effect is suspected to work in combination with the effect of competition between rattan plants/clumps and other understorey vegetation. The combination of natural competition and anthropogenic factors causes adverse effects on tree-stem density.

The impacts of timber extraction were found to be supplemental and minor, but this study did not focus on timber and samples were only limited. Despite the non-significant result, there are indications that less-disturbed areas have positive impacts on tree growth and higher primary productivity.

The current structure of the forest is also the result of past forest dynamics. Past human disturbance, from forest dwelling and shifting cultivation that took place in Lambusango forest up to the late 1960s, could impact on the current structure. Descriptions based on historical documents as well as anecdotal information from local informants suggest that forest dwelling took place at least since the early 1930s. Efforts to include past forest activities in analyses were hindered by limited historical data.

8.1.5 Socio-economic characteristics affecting cane harvest levels

Chapter Six focused on rattan cane harvesters. As an income source, cane harvesting is assumed to be driven by the socioeconomic characteristics of the harvesters. Since rattan cane harvesting in the Lambusango area is mostly an informal/secondary job, influences of the main livelihood activities such as farming and/or non-farm jobs were assessed. Harvesting is seasonal which makes it beneficial as a supplemental income source during off-farming months. Few harvesters are engaged in other forest-related activities such as timber extraction and honey collection, although due to its illegality, it is likely that more harvesters are engaged in timber extraction than were actually recorded.

The proportion of rattan income from total income, or rattan dependence, is varied among farmers. In some villages, harvesters are not dependent on rattan cane harvesting, while in others they are highly dependent. Demographic factors affect rattan cane harvesting activities only marginally. The effect of harvester age on rattan return to labour implies that the daily return of a manual and rigorous livelihood activity such as rattan cane harvesting is affected by the physical strength of the actors. Dependence, annual income and daily net return from wild rattan cane harvesting in Lambusango forest were not found to be significantly affected by the socioeconomic characteristics of the harvesters tested in this study. There is an indication, however, that a higher income from non-rattan harvesting sources, especially agriculture, is associated with lower harvesting daily income. More profitable, more intensive and less rigorous livelihood activities are favoured by some harvesters, making them less active harvesters, and therefore less dependent on rattan.

8.1.6 Sustainability of rattan cane harvesting in Lambusango

Chapter 7 focused on two aspects: continuing the search for the key factors affecting harvest levels and harvesting preferences and the sustainability of rattan cane harvesting in the study area.

Cane harvesters in Lambusango forest show preferences for other income sources. However, the profitability of any income source is the major factor behind preferences. Therefore, for rattan cane harvesting, the sale price is an important factor in deciding whether people persist with cane harvesting or change to alternative income sources. National and sub-national policies which affect demand and price were found to influence cane production. The decreasing relative price to rice in recent years seems to have created disincentives for cane harvesting. And despite limitations in the data, there was a pattern of increasing labour absorption in most of the subdistricts in line with decreasing cane production levels.

Resource sustainability was assessed for the two most commercial rattan species, *C. zollingeri* and *C. ornatus*. Harvestable cane abundance seems to be sustainable by maintaining a low level of harvesting. The majority of harvesters perceive rattan cane abundance to be constant or increasing in the forest. Impacts on forest and vegetation structure are considered minimum and the profitability of cane harvesting is better than daily wages from other labour jobs available in the villages. The economic viability of rattan harvesting interrelates with ecological and botanical characteristics in determining sustainability of the species having high commercial value. Characteristics such as clustering rattan and fast growth rate will support the economic viability of cane harvesting as well as resource sustainability; therefore, the discussions on both issues become inseparable.

Driven by diverging issues and circumstances surrounding the continuation of rattan cane harvesting, two conceptual scenarios for the future of Lambusango forest were discussed: sustainable harvesting and non-forest-based livelihoods. Suggested actions proposed under the sustainable harvesting scenario include review and adjustments of conservation zones and regulation, thorough resource assessments and monitoring, understanding of ecological sustainability by local harvesters and improved harvesting techniques. Two potential risks that might emerge from the non-forest based livelihood scenario are the potential for illegal activities and land conversion pressures at the forest edges. Under this scenario, the development of rattan cultivation in agroforestry systems in the forest buffer zone was considered. It could be an effective approach to gradually encourage harvesters away from the core forest area and/or conservation forest areas. A gradual and voluntary approach is regarded as crucial for the fairness and justice in dealing with villagers that have been dependent on the neighbouring forest for generations.

8.2 Further reflections

This PhD study has produced key findings which can contribute to discussions both in the local context of Lambusango and Buton and in wider debates on NTFP harvesting as part of sustainable livelihoods in forest conservation areas. Throughout the research, the author has reflected on some points which are not directly related to the foci of the PhD. However, as those points are relevant to the broader context of this research, the following sections discuss them briefly and serve as a bridge to ongoing efforts and discussions, ranging from Lambusango forest management initiatives by Lambusango Forest Conservation Programme (LFCP), to wider NTFP discussions and global initiatives on sustainable forestry.

8.2.1 Rattan cane harvesting in the context of Lambusango forest management

Concern over rattan harvesting in the conservation areas is one of the issues with regards to conservation enforcement in the field and local people's livelihood activities in the forest (Purwanto, 2008b). Within LFCP, which this PhD study is a part of, there have been a number of initiatives and actions in collaboration with various stakeholders to ensure that the forest is protected, management is conducted sustainably and local peoples' non-forest livelihood activities are strengthened.

The Community Forestry Management Forum (CFMF) established by LFCP has successfully opposed the establishment of mining areas and an oil palm plantation, facilitated the control of forest encroachments and strengthened forest protection. Other major achievements of the LFCP relate to the development of sustainable livelihood models for villages surrounding the forest. These efforts have included the promotion of ginger farming and its marketing, facilitating cashew nut fair-trade certification, strengthening the farmers' capacity in oyster farming and facilitating the marketing of organic coffee (see Purwanto, 2008a for details). Specifically on rattan cane extraction issues, Purwanto (2008b) discussed some concerns that were thought to impede sustainable rattan harvesting, mainly misconduct in the licensing and post-harvest procedures by the local authorities and on the issues of concession boundaries. Further, it was suggested to initiate rattan cultivation by rattan harvesters in the surrounding villages (Purwanto, 2008b).

Forest conservation in the Lambusango area can benefit from the results of this study as they provide previously unavailable information on different aspects of the current status of the forest: forest structure, profitability of forest products and the actors benefiting from the products. It is essential that forest management understands the factors underlying human activities in the forest as well as the extent of the disturbance caused by human activities. Through this study, comprehensive assessments have been made and, as presented in Chapter Seven, several suggested actions for consideration of the future of sustainable rattan cane harvesting have been indicated. In line with LFCP efforts with regards to sustainable rattan cane extraction, the suggested actions discussed in this study are expected to contribute to the design of forest conservation which largely involves local people's support and management.

8.2.2 Lambusango rattan: a revisit of NTFP discussions

During the late 1990s to the early 2000s, a wide range of issues, ideas and concerns related to balancing forest conservation and development were discussed by scholars working on forestry and natural resource management. The contribution of NTFPs to forest conservation and livelihood improvement were widely discussed and published. Considering the continued problems surrounding NTFP extraction and related issues in many parts of the developing world, the scope and directions of a study such as this continue to be relevant and applicable.

As indicated by the literature reviewed in this study, a number of major issues emerge in the debates on NTFP extraction. First, whether it is an activity that improves rural 'poor' livelihoods, secondly whether as a forest-based activity it is in line with forest conservation efforts and whether the extractions are commonly sustainable. This study has shown the relevance of those debates in the Lambusango context. The importance of rattan cane harvesting to local livelihoods has been as an informal source of income, but having a major role as a cash source. Despite the common preference by harvesters to be engaged in a less rigorous activity than cane harvesting, the abundance of rattan resources is shown to be economically beneficial to the local people.

Regarding the emerging questions on the roles of NTFP extraction in forest conservation, evidence was found to be agreeable with the initial concept of NTFP extraction. Despite the mixed opinions, local villagers are notably in favour of maintaining forest if forest is beneficial to them, which in this case means direct economic benefits.

Issues regarding sustainable NTFP extraction are especially contentious when commercialisation is promoted and ecological impacts and resource sustainability are at stake. Cane harvesting in Lambusango forest may not need to become fully commercialised because there are diverse sources of income, mainly from agricultural cash crops, that have been and can be promoted as the main local livelihood strategy. Considering the dynamics of diverse sources of income, sustainable extraction is potentially implementable provided that related local stakeholders work hand in hand to make it succeed. For wild rattans, especially when growing in forest with conservation importance, promoting fully commercial and market-oriented cane harvesting will certainly discourage sustainability. Evidence indicates minimum impacts on forest structure and diversity, and this can contribute positively to the discussions on ecological impacts of NTFP extraction especially for a commercial product like rattan cane.

8.2.3 Further initiatives for sustainable forest management

Sustainable forest management continues to evolve and has now become a focus in global forestry. During these past two decades, initiatives in promoting sustainable forestry have been widely reinforced in response to the 1992 Rio Earth Summit, particularly based on the 'Forest Principles' document (United Nations, 2000). Forest management in developing countries needs support from the global societies because of lack of resources for planning, implementation and monitoring of the maintenance of forest resources to ensure sustainability (FAO, 2009b). Consequently, a number of schemes and plans have been initiated to assist governments, local governments or local organizations to secure sustainability of forest resources while improving livelihoods of local people.

8.2.3.1 Local and national initiatives

Initiatives by LFCP for Lambusango forest in local to district level efforts have proven successful at initiating sustainable forest management in combination with efforts to strengthen local livelihood options. Findings of this study are expected to support LFCP efforts by providing better knowledge of long standing forest product extraction in forest with conservation values. The findings can serve as useful insights for the national forestry authorities regarding the complexity of the issues, not only in the Lambusango area but also in other parts of the country. As implied by the 'sustainable harvesting' scenario discussed in this thesis, dialogues between authorities that govern forest product extraction and those that regulate forest protection and conservation need to take place to improve the situation on the ground.

With regards to the development of agroforestry systems, a new forest management scheme has been introduced by national forestry authorities called *Hutan Desa* (Village Forest). The 'Village Forest' scheme was set up with the objectives of providing local villagers access to forest resources as part of sustainable forest management and sustainable livelihoods (Ministry of Forestry, 2008; Masyhud, 2008). 'Village Forest' status can be proposed by local authorities for forests located within the administrative boundaries of villages that do not yet hold concession rights (Ministry of Forestry, 2008; Masyhud, 2008). For the Lambusango area, this scheme may have potential for developing rattan agroforestry in the forest 'buffer zone' as opposed to harvesters' private farmlands. This fits better with the traditional concept and local preference for having rattans in the forest area in the close vicinity of harvesters' dwellings. This also reinforces the concept of rattan concession areas. Implementation of this scheme may also reduce the risk of trespassing into conservation forest.

8.2.3.2 Potential external-market schemes

It is relevant to briefly touch upon external opportunities that might be useful for Lambusango in the future. The following discussions introduce opportunities and challenges that might be applicable from the perspectives of both embracing sustainable rattan cane extraction and maintaining forest cover and standing biomass.

NTFP certification could be appropriate for Lambusango rattan canes. NTFP certification is a global market mechanism that allows a higher price or 'premium price' for NTFPs produced from sustainably managed forests in developing countries. It has been recognised, however, that NTFP certification is much more complex than timber certification because it deals with a wider range of products and a wider range of extraction methods, and can involve complex legality issues since NTFPs are mostly extracted by poor local people having no legal tenure over the forest that the products are extracted from (Pierce *et al*., 2003; Shanley *et al*., 2008). The process for achieving a certified label involves a complex web of social, legal, ecological, economic and technical elements and a range of actors from producers, certifiers and companies (Pierce *et al*., 2003). Therefore, for rattan canes in Lambusango, it is clearly a long route to eventually enter a certified-NTFP market. However, it is a relevant scheme for stakeholders to consider, providing incentives for local harvesters to maintain sustainable rattan cane extraction.

Payments for Environmental Services (PES) is a scheme that provides incentives for forest or environmental conservation through direct payment from the beneficiary to the provider of the service(s). In brief, PES can be defined as *'a direct and voluntary payment made by a beneficiary, who benefits from a well-defined environmental service, to a provider, who maintains the continuation of the service'* although it has been recognised that it is based on stringent requirements and technicalities (Wunder, 2005 and 2007). The environmental service in question may cover each or a combination of biodiversity conservation, watershed protection, carbon sequestration and landscape beauty. Several case studies have shown both the potential and limitations of the scheme in developing countries for different services (e.g. Ibarra Gené, 2007; Clements *et al.,* 2009; George *et al.,* 2009). Reviews based on a large number of case studies in various countries have identified some caveats and concerns on the implementation and efficiency of PES (Landel-Mills and Porras, 2002; Wunder, 2007). As a pro-poor market mechanism, some of the obstacles involve the high transaction cost and land tenure issues, in which the poor lack power (Landel-Mills and Porras, 2002). Wunder (2007) drew similar conclusions and in addition, the author also included and identified the issues of 'threats', 'opportunity cost' and 'additionality' which complicate the design and implementation of PES for tropical forest conservation. Therefore, despite the potential, many challenges are yet to be overcome for PES to work successfully for tropical forest conservation and in a poverty-dominated area such as Lambusango forest.

A more recent incentive approach has emerged within the context of climate change mitigation. The REDD (Reducing Emission from Deforestation and forest Degradation) scheme is a recent effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development (UN-REDD, 2009). The background to this scheme was the estimation that deforestation and forest degradation, through agricultural expansion, conversion to pastureland, destructive logging, etc., account for nearly 20% of global greenhouse gas emissions, which is second after the energy sector (UN-REDD, 2009). Therefore, countries that are willing and able to reduce emissions from deforestation and forest degradation should be financially compensated (Parker *et al*., 2008; Angelsen, 2008; Peskett *et al*. 2008). It is suggested that REDD can bring the multiple benefits of conserving biodiversity and other ecosystem services (Angelsen, 2008), taking into account the importance of forest for local and indigenous people (UN-REDD, 2009) and adding objectives of poverty alleviation (Angelsen, 2008; Peskett *et al*. 2008). In Indonesia, these latter factors are essential to discussions because most forests are government-owned but are important livelihood sources for many local and/or indigenous communities that mostly live in poverty.

It is premature, at this stage, to judge the fitness of the schemes such NTFP certification, PES and REDD for Lambusango forest, and Buton forests in general. However, it is beneficial to recognise that there are potential external initiatives that can accommodate the need to ensure sustainable forest management and local livelihood improvements. As opposed to the ongoing conventional approaches that are characterised by separate actions for forest protection, sustainable forest product extraction and livelihood improvements, incentive and payment schemes may offer an integrated rewarding mechanism in which forest protection and livelihood improvements become a bundled target.

8.2.3.3 Final remarks

These external schemes clearly require full support from government and/or non-government bodies. In addition to the complications of implementation and mechanisms, challenges and controversies are inevitable when introducing such new ideas. It is realised that these schemes are not well tested and limitations and cautions have been identified based on experiences in other areas. Therefore, it is best that such new external market opportunities are incorporated in addition to the ongoing and more realistic local efforts. By securing economic and ecological sustainability of the existing and potential livelihood options in the Lambusango area, e.g. sustainable rattan cane harvesting, sustainable agriculture resulting from LFCP efforts and the potential of rattan agroforestry, these schemes may be useful as supplementary efforts rather than as the main poverty remedy which may create other types of vulnerability.

Finally, for the Lambusango area, a forest extraction activity such as rattan cane harvesting is long-standing and important for local people's livelihood. Evidence showed that only minimum impacts have occurred on forest structure and harvesting can be maintained at a sustainable level. While major livelihood activities in the Lambusango area are clearly focussed on agriculture and there are several potential livelihood improvement options, rattan cane harvesting can function as a secondary livelihood strategy and a livelihood safety net. A long-term sustainable harvesting scheme clearly requires participation and commitment from various related stakeholders. However, despite the challenges, with the evidence of harvesting being ecologically-benign and economically-important, this activity should be supported and reinforced towards a fully sustainable practice.

Appendices

Appendix 1. Land cover class description

Forested areas are differentiated into:

- Inland near-primary forest
- Mangrove forest
- Degraded forest, secondary growth

The development of dry agriculture in the areas surrounding the forest is considered the main reason for forest clearing. The shifting cultivation system practiced for generations also impacts on the natural vegetation cover. The land covers outside forest are classified to represent both the main farming systems and the natural-covers:

1. Tree-based farming systems→ ranging from monoculture gardens up to shrubby gardens (Figure A1.1)
2. Non-tree crops, herbaceous vegetation → e.g. cassava, maize, vegetables, which are mostly sparsely intercropped with banana, opened-land grown with grass and herbaceous vegetation, also naturally herbaceous grassland (see Figure A1.2)
3. Inundated areas, paddy ricefield (Figure A1.3)
4. Cleared land, bareland → the recently opened/cleared area, non vegetated area, asphalt
5. Other classes which are considered as 'no data' values are: tidal areas, sea and water, shadow and cloud cover.

Figure A1.1. Cashew gardens (left), multistrata coconut-cacao gardens (middle) and shrubby cashew gardens (right)

Figure A1.2. Recently-opened land (left) and herbaceous vegetation (right)

Figure A1.3. Inundated paddy ricefield

Appendix 2. Land cover maps 1991-2006

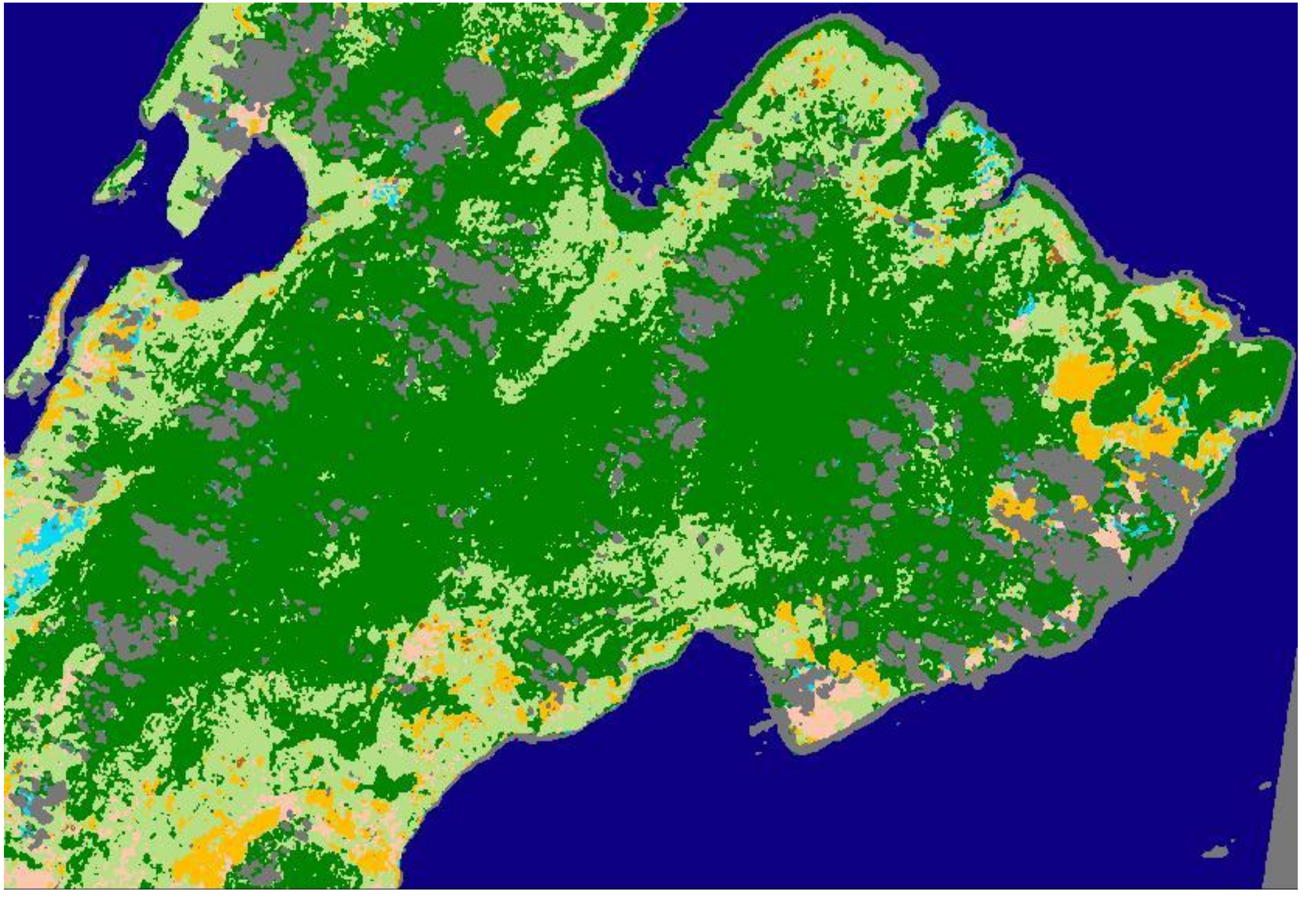


Figure A2.1. 1991 Land cover map

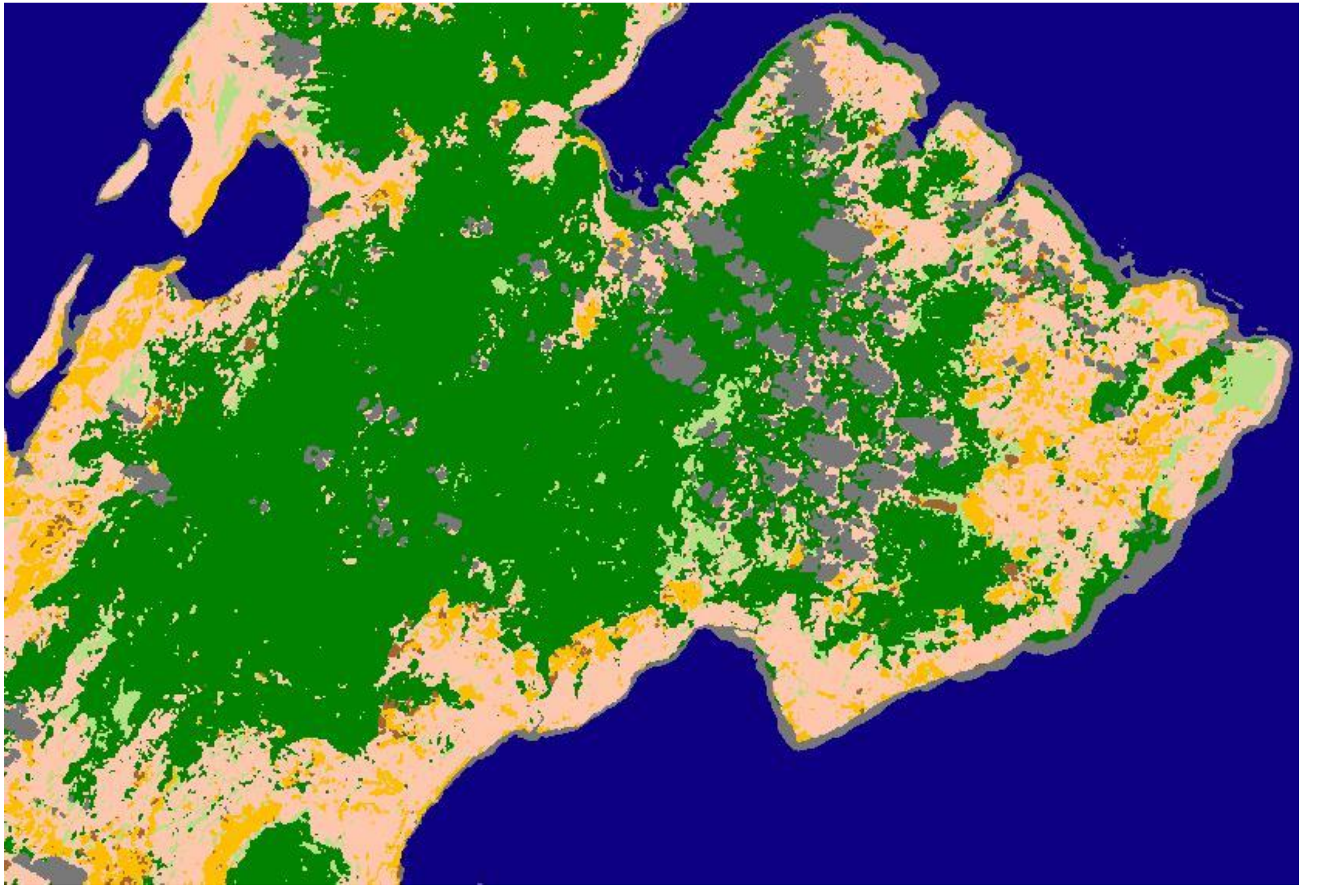


Figure A2.2. 2004 Land cover map

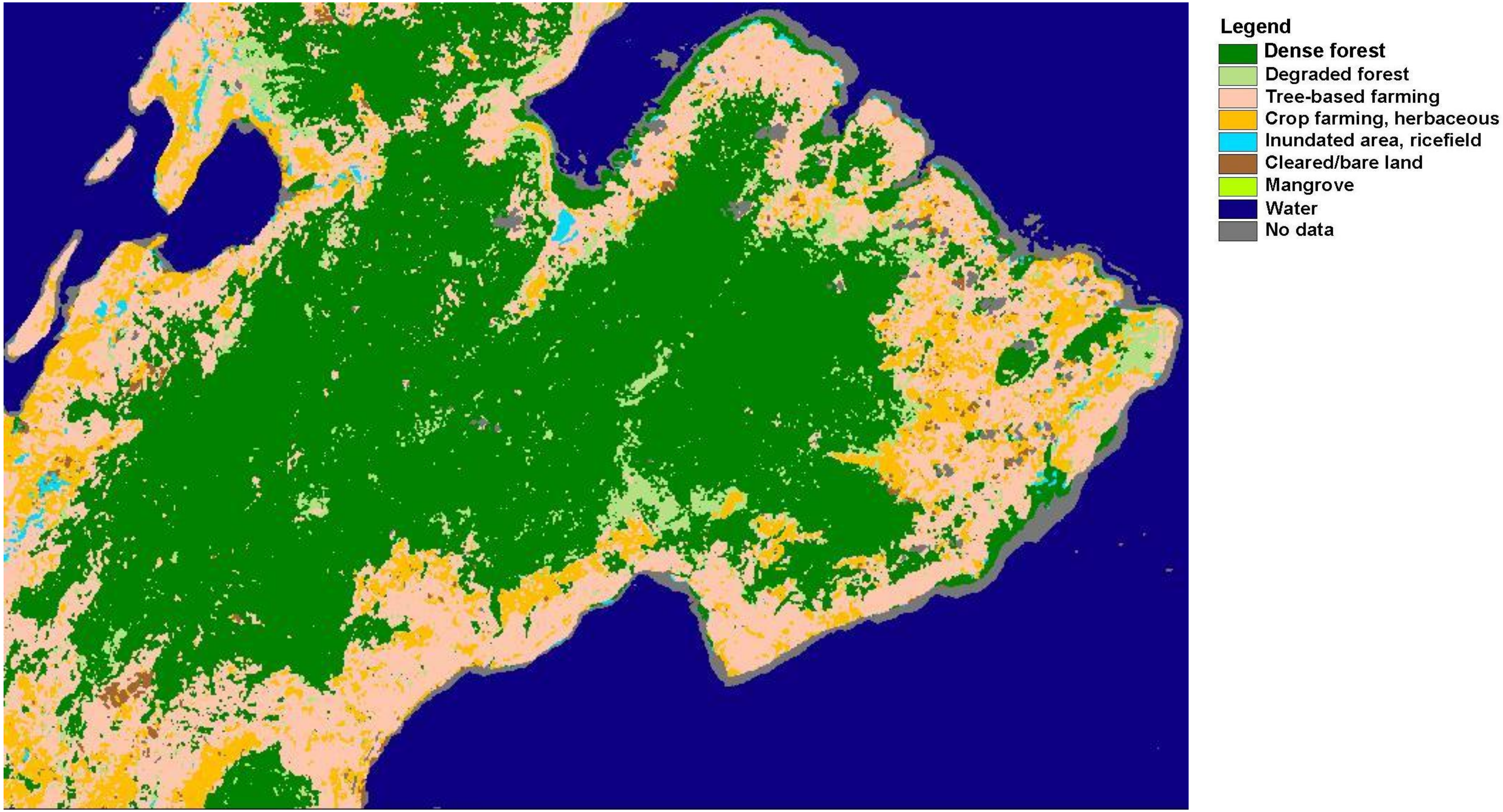


Figure A2.3. 2006 Land cover map

Appendix 3. Tables of statistic summaries and AIC_c scores

Table A3.1. Statistics and AIC_c scores of multiple linear regressions between AGB and Landsat TM derived attributes

	Coefficients	Std. Error	p-value	R^2	Adjusted R^2	F-statistics	df	p-value (model)	AIC_c score	Delta AIC_c
Enter				0.237	0.180	4.147	3	0.012	456.253	0
(Constant)	3222.02	1477.27	0.035							
B5t5_corr	-223.92	103.44	0.036							
ND54	-1421.11	698.37	0.049							
B1rflmean3	-27518.61	17828.07	0.131							
Stepwise				0.116	0.095	5.528	1	0.023	457.749	1.496
(Constant)	347.22	27.01	0.000							
B5t5_corr	-251.51	106.97	0.023							
Backward				0.237	0.180	4.147	3	0.012	456.253	0
(Constant)	3222.02	1477.27	0.035							
B5t5_corr	-223.92	103.44	0.036							
ND54	-1421.11	698.37	0.049							
B1rflmean3	-27518.61	17828.07	0.131							
Forward				0.116	0.095	5.528	1	0.023	457.749	1.496
(Constant)	347.22	27.01	0.000							
B5t5_corr	-251.51	106.97	0.023							

Note: Refer to Table 2.4 for abbreviations

Table A3.2. Statistics and AIC_c scores of multiple linear regressions between individual annual harvest and accessibility variables

	Coefficients	Std. Error	p-value	R^2	Adjusted R^2	F-statistics	df	p-value (model)	AIC_c score	Delta AIC_c
Enter				0.783	0.674	7.22	2	0.047	122.41	11.2
(Constant)	531.26	2607.86	0.849							
PC1-slopefactor	1150.73	566.68	0.112							
Farthdist	0.50	0.36	0.234							
Stepwise				0.676	0.612	10.45	1	0.023	111.21	0
(Constant)	4138.91	463.46	0.000							
PC1-slopefactor	1618.07	500.59	0.023							
Backward				0.783	0.674	7.22	2	0.047	122.41	11.2
(Constant)	531.26	2607.86	0.849							
PC1-slopefactor	1150.73	566.68	0.112							
Farthdist	0.50	0.36	0.234							
Forward				0.676	0.612	10.45	1	0.023	111.21	0
(Constant)	4138.91	463.46	0.000							
PC1-slopefactor	1618.07	500.59	0.023							

Note: PC1-slopefactor = slope factor; Farthdist=farthest distance

Table A3.3. Statistics and AIC_c scores of multiple linear regressions between village annual harvest and accessibility variables

	Coefficients	Std. Error	p-value	R^2	Adjusted R^2	F-statistics	df	p-value (model)	AIC_c score	Delta AIC_c
Enter				0.836	0.754	10.175	2	0.027	2.257	12.48
(Constant)	3.629	0.488	0.002							
PC1-slopefactor	0.105	0.106	0.380							
Farthdist	0.000	0.000	0.041							
Stepwise				0.796	0.755	19.490	1	0.007	-10.220	0
(Constant)	3.350	0.397	0.000							
Farthdist	0.000	0.000	0.007							
Backward				0.796	0.755	19.490	1	0.007	-10.220	0
(Constant)	3.350	0.397	0.000							
Farthdist	0.000	0.000	0.007							
Forward				0.796	0.755	19.490	1	0.007	-10.220	0
(Constant)	3.350	0.397	0.000							
Farthdist	0.000	0.000	0.007							

Note: PC1-slopefactor = slope factor; Farthdist=farthest distance

Table A3.4. Parameter estimates for univariate ANCOVA between individual harvest level and designated forest zones

Parameter	B coeff.	Std. Error	t	p-value	Eta squared
Intercept	-3176.34	3426.49	-0.927	0.357	0.010
Farthest Distance*	0.66	0.44	1.485	0.141	0.026
Slope factor*	1971.91	668.51	2.950	0.004	0.096
Conservation zone	3740.52	1766.44	2.118	0.037	0.052
Adjacent to Conservation zone	2211.34	1223.09	1.808	0.074	0.038
Production Forest	0.00	.	.	.	

* *covariables*

Table A3.5. Statistics and AIC_c scores of multiple linear regressions between annual rattan income and demographic and socioeconomic variables

	Coefficients	Std. Error	p-value	R^2	Adjusted R^2	F-statistics	df	p-value	AIC_c score	Delta AIC_c
Enter				0.699	0.681	37.71	5	0.000	-231.63	4.60
(Constant)	-0.309	0.573	0.592							
LogTotInc	1.792	0.132	0.000							
LgIncNoRat	-0.867	0.086	0.000							
SqTotaLand	0.000	0.001	0.978							
SqHHMembers	0.009	0.076	0.902							
PC1_WI	-0.043	0.032	0.189							
Stepwise				0.691	0.684	94.07	2	0.000	-236.23	0
(Constant)	-0.183	0.532	0.732							
LogTotInc	1.777	0.131	0.000							
LgIncNoRat	-0.867	0.085	0.000							
Backward				0.699	0.681	37.71	5	0.000	-231.63	4.60
(Constant)	-0.309	0.573	0.592							
LogTotInc	1.792	0.132	0.000							
LgIncNoRat	-0.867	0.086	0.000							
SqTotaLand	0.000	0.001	0.978							
SqHHMembers	0.009	0.076	0.902							
PC1_WI	-0.043	0.032	0.189							
Forward				0.691	0.684	94.07	2	0.000	-236.23	0
(Constant)	-0.183	0.532	0.732							
LogTotInc	1.777	0.131	0.000							
LgIncNoRat	-0.867	0.085	0.000							

Note: LogTotInc=total annual income (in $\log_{10}$), LgIncNoRat=annual non-rattan income (in $\log_{10}$), SqTotaLand = total land area (in square root), SqHHMembers = number of household members (in square root), PC1_WI = Wealth index

Table A3.6. Statistics and AIC_c scores of multiple linear regressions between rattan dependence and demographic and socioeconomic variables

	Coefficients	Std. Error	p-value	R^2	Adjusted R^2	F-statistics	df	p-value	AIC_c score	Delta AIC_c
Enter				0.740	0.724	46.226	5	0.000	42.67	4.77
(Constant)	7.096	2.772	0.012							
LogTotInc	5.383	0.640	0.000							
LgIncNoRat	-5.825	0.415	0.000							
SqTotaLand	0.000	0.003	0.920							
SqHHMembers	0.043	0.366	0.906							
PC1_WI	-0.190	0.156	0.228							
Stepwise				0.734	0.728	115.881	2	0.000	37.90	0
(Constant)	7.604	2.573	0.004							
LgIncNoRat	-5.827	0.412	0.000							
LogTotInc	5.320	0.631	0.000							
Backward				0.740	0.724	46.226	5	0.000	38.02	0.12
(Constant)	7.096	2.772	0.012							
LogTotInc	5.383	0.640	0.000							
LgIncNoRat	-5.825	0.415	0.000							
SqTotaLand	0.000	0.003	0.920							
SqHHMembers	0.043	0.366	0.906							
PC1_WI	-0.190	0.156	0.228							
Forward				0.734	0.728	115.881	2	0.000	37.90	0
(Constant)	7.604	2.573	0.004							
LgIncNoRat	-5.827	0.412	0.000							
LogTotInc	5.320	0.631	0.000							

Note: LogTotInc=total annual income (in log_{10}), LgIncNoRat=annual non-rattan income (in log_{10}), SqTotaLand = total land area (in square root), SqHHMembers = number of household members (in square root), PC1_WI = Wealth index

Table A3.7. Statistics and AIC_c scores of multiple linear regressions between Rattan Return to Labour (RRtL) and demographic and socioeconomic variables

	Coefficients	Std. Error	p-value	R^2	Adjusted R^2	F-statistics	df	p-value	AIC_c score	Delta AIC_c
Enter				0.162	0.110	3.131	5	0.012	675.69	6.68
(Constant)	-77.21	105.40	0.466							
LogTotInc	83.48	24.34	0.001							
LgIncNoRat	-45.04	15.77	0.005							
SqTotaLand	-0.04	0.10	0.688							
SqHHMembers	3.47	13.93	0.804							
PC1_WI	-9.85	5.95	0.102							
Stepwise				0.160	0.139	7.970	2	0.013	669.01	0
(Constant)	230.01	22.75	0.000							
age	-1.74	0.51	0.001							
ethnicity	26.68	10.50	0.013							
Backward				0.160	0.129	5.255	3	0.002	671.26	2.24
(Constant)	-79.74	98.19	0.419							
LogTotInc	84.65	23.95	0.001							
LgIncNoRat	-45.45	15.57	0.005							
PC1_WI	-10.59	5.12	0.042							

Note: LogTotInc=total annual income (in $\log_{10}$), LgIncNoRat=annual non-rattan income (in $\log_{10}$), SqTotaLand = total land area (in square root), SqHHMembers = number of household members (in square root), PC1_WI = Wealth index

Appendix 4. Rattan description

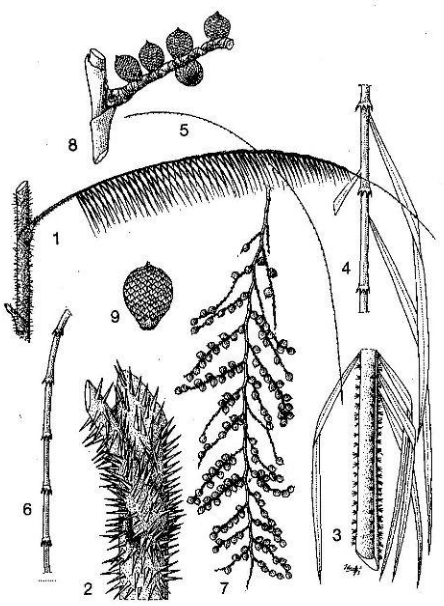
Identification in the field was in collaboration with Dr Andrew Powling based on Powling (2009) and plant description and diagrams are from Dransfield and Manokaran (1994).

1. *Calamus zollingeri* Becc. *(Mombi)*

A large diamater rattan, 25-40 mm, good quality cane

Clustering, robust, dioecious rattan.

Ecology: found in primary forest, from lowlands to 800 m asl.



Calamus zollingeri Beccari – 1, sheathed stem and leaf; 2, leaf-sheath; 3, basal part of leaf; 4, upper part of leaf; 5, cirrus; 6, detail of cirrus; 7, part of infructescence; 8, detail of infructescence; 9, fruit.

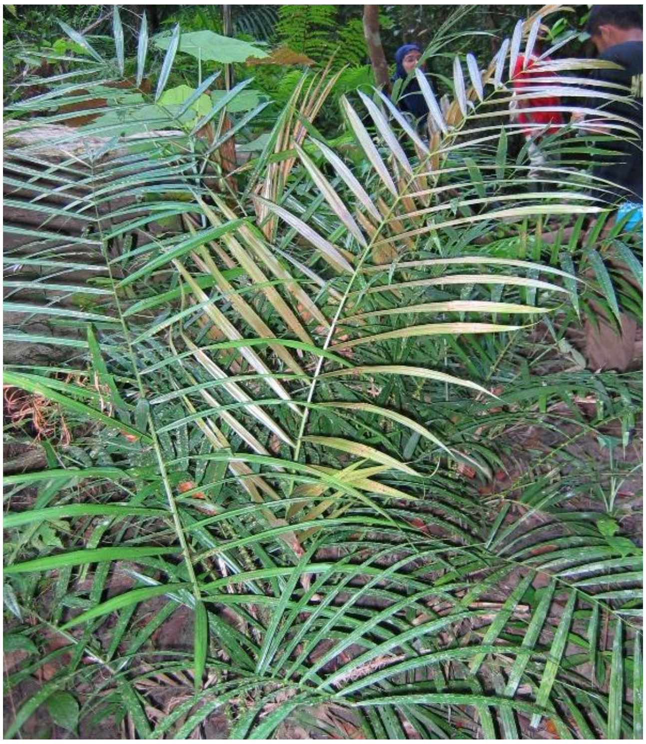


Figure A4.1. *Calamus zollingeri* Becc. *(Mombi)*

2. *Calamus zollingeri* Becc. *(Batang Asli)*

A large diamater rattan, 25-40 mm, good quality cane

Clustering, robust, dioecious rattan.

Ecology: found in primary forest, from lowlands to 800 m asl.

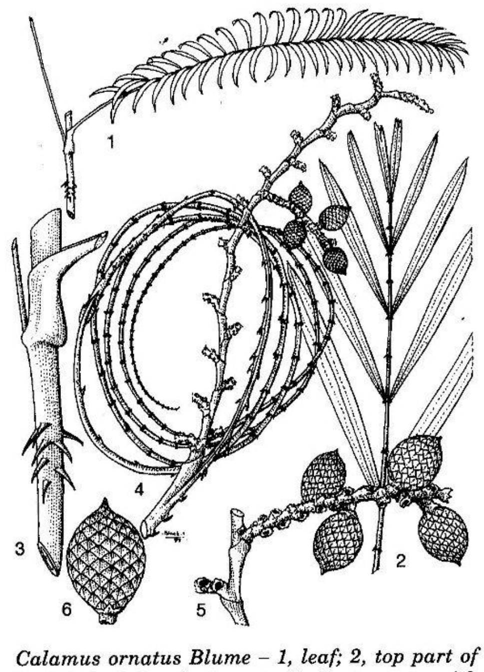
Figure A4.2. *Calamus zollingeri* Becc. *(Batang Asli)*

3. ***Calamus ornatus var. ornatus Blume (Lambang)***

Massive clustering rattan, climbing to 50 m length

Very distinctive, not easily confused with other *Calamus*

Ecology: common in primary and secondary forest , altitude up to 1000 m asl; NOT found in peatswamp and ridgetops



Calamus ornatus Blume – 1, leaf; 2, top part of leaf; 3, leaf-sheath; 4, part of infructescence with apical flagellum; 5, part of infructescence; 6, fruit.

Figure A4.3. *Calamus ornatus var. ornatus Blume (Lambang)*

4. *Calamus sp. (Kabe)* – N/A in Dransfield and Manokaran, 1994

Figure A4.4. *Calamus sp. (Kabe)*

5. *Calamus symphysipus (Umbul)*

Solitary rattan

Ecology: found on steep slopes in lowland forest up to 500 m asl

Figure A4.5. *Calamus symphysipus (Umbul)*

6. *Calamus leiocaulis (Daramasi)*

Sparsely clustering rattan, slender stem

Ecology: lowland primary forest, rather wet soils, up to 50 m asl

Figure A4.6. *Calamus leiocaulis (Daramasi)*

7. *Calamus mindorensis* Becc. *(Hoa)*- N/A in Dransfield and Manokaran, 1994

Figure A4.7. *Calamus mindorensis* Becc. *(Hoa)*

8. *Calamus sp. Nov2. (Tohiti)* – N/A in Dransfield and Manokaran, 1994

Figure A4.8. *Calamus sp. Nov2. (Tohiti)*

9. *Calamus minahassae (Kai Sisau)*

Solitary or clustering rattan, slender stem

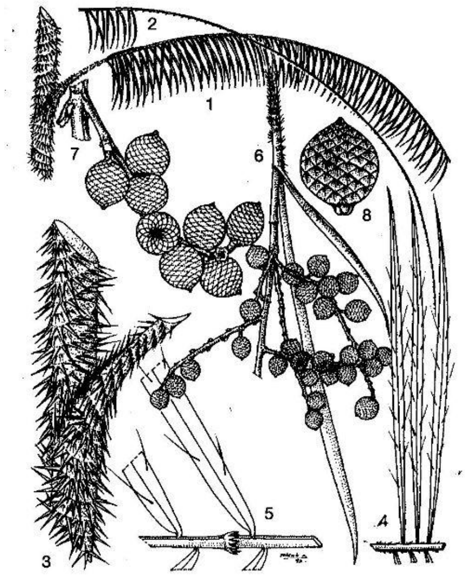
Ecology: lowland to montane forest up to 1000 m asl

Figure A4.9. *Calamus minahassae (Kai Sisau)*

10. *Daemonorops robusta (Noko)*

Clustering dioecious rattan, up to 20 m tall

Ecology: lowland forest up to 100 m asl, usually near streams



Daemonorops robusta Warb. – 1, sheathed stem and basal part of leaf; 2, upper part of leaf with cirrus; 3, leaf-sheath; 4, three leaflets; 5, detail of rachis with leaflets; 6, part of infructescence; 7, detail of infructescence; 8, fruit.

Figure A4.10. *Daemonorops robusta (Noko)*

11. *Calamus sp. 1 (Bulurusa)* - N/A in Dransfield and Manokaran, 1994

Figure A4.11. *Calamus sp. 1 (Bulurusa)*

12. *Calamus koordersianus* Becc. *(Torumpu)*

Clustering, sometimes solitary rattan

Distribution: only Sulawesi

Figure A4.12. *Calamus koordersianus* Becc. *(Torumpu)*

13. *Calamus pedicellatus* Becc. ex K.Heyne *(Ngasa)* – N/A in Dransfield and Manokaran, 1994

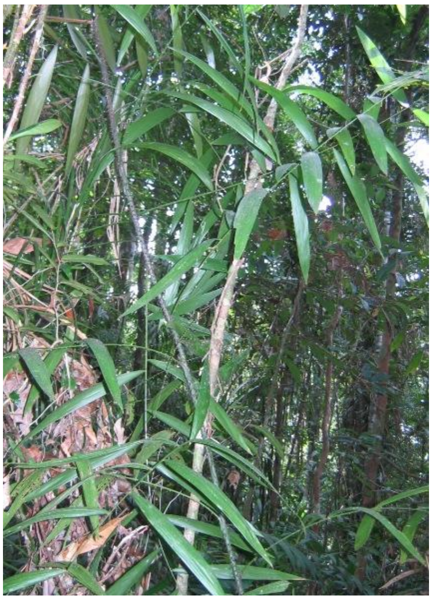


Figure A4.13. *Calamus pedicellatus* Becc. ex K.Heyne *(Ngasa)*

14. *Calamus suaveolens* W.J. Baker & J.Dransf. *(Lakumpa)*- N/A in Dransfield and Manokaran, 1994

Figure A4.14. *Calamus suaveolens* W.J. Baker & J.Dransf. *(Lakumpa)*

15. *Calamus sp. 4 (Batu)* - N/A in Dransfield and Manokaran, 1994

Figure A4.15. *Calamus sp. 4 (Batu)*

Appendix 5. GIS approach and participatory mapping to produce RHZ - example of Walompo Village

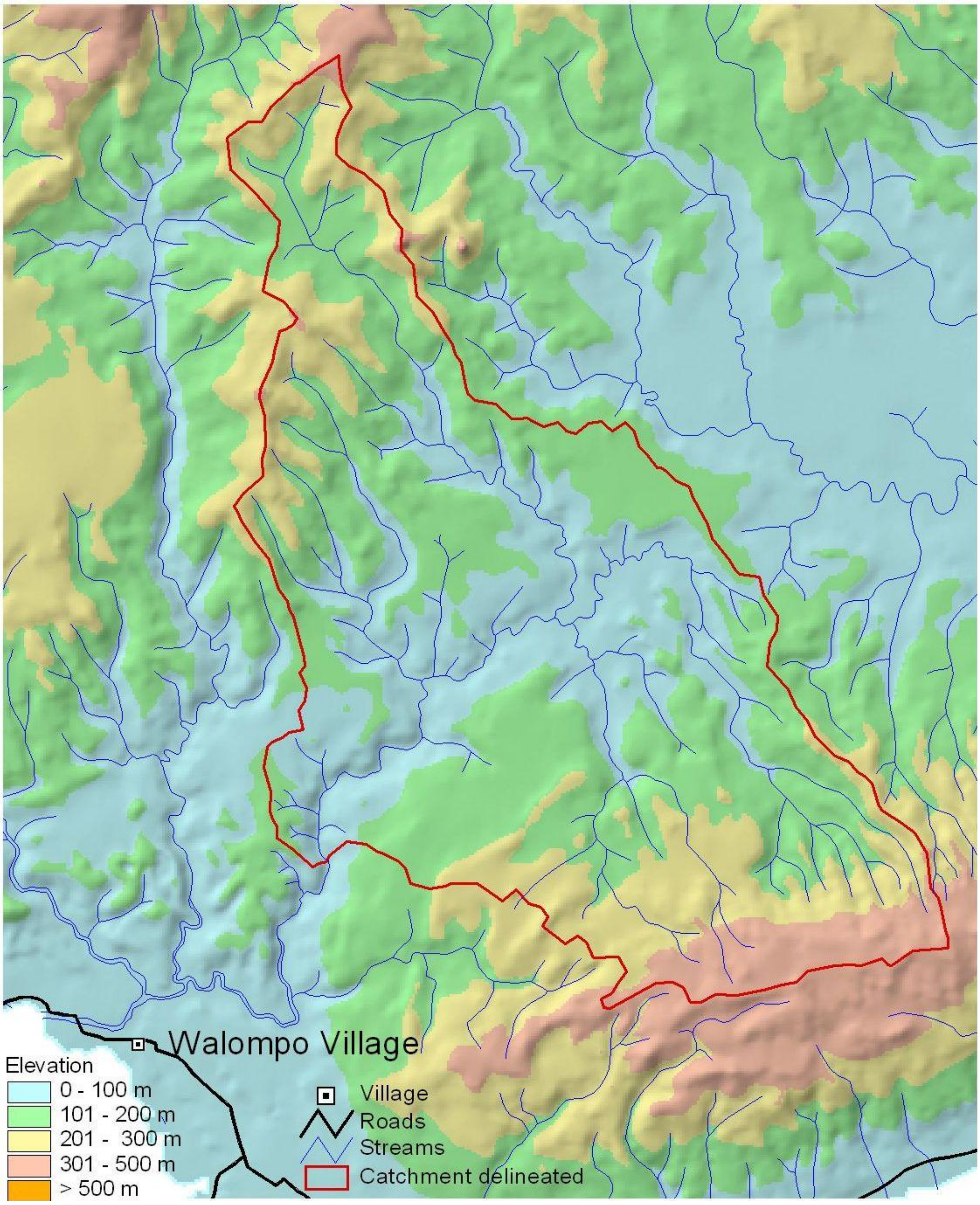


Figure A5.1. Catchment delineation from GIS

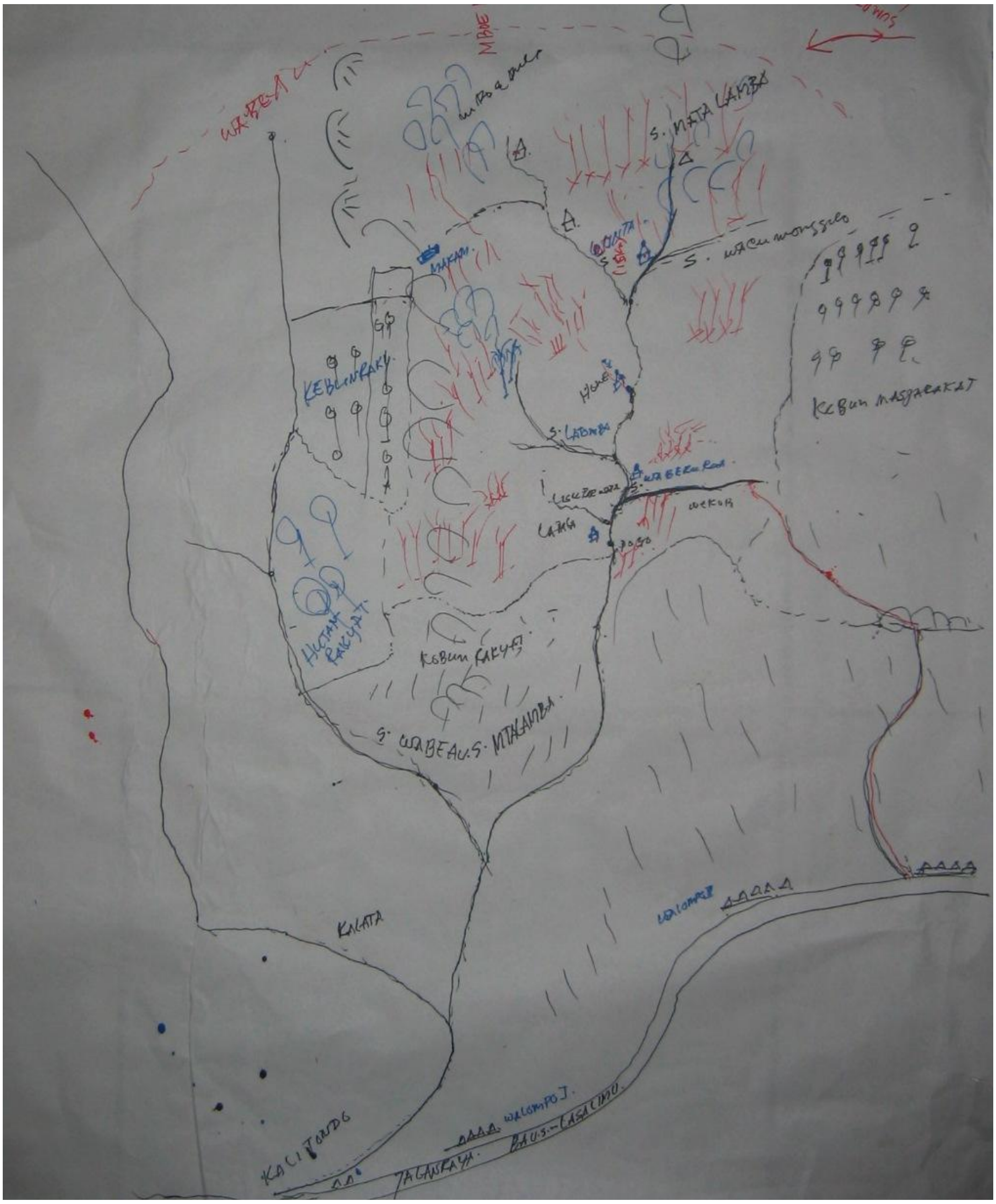


Figure A5.2. Sketch map of rattan harvesting destination in the forest

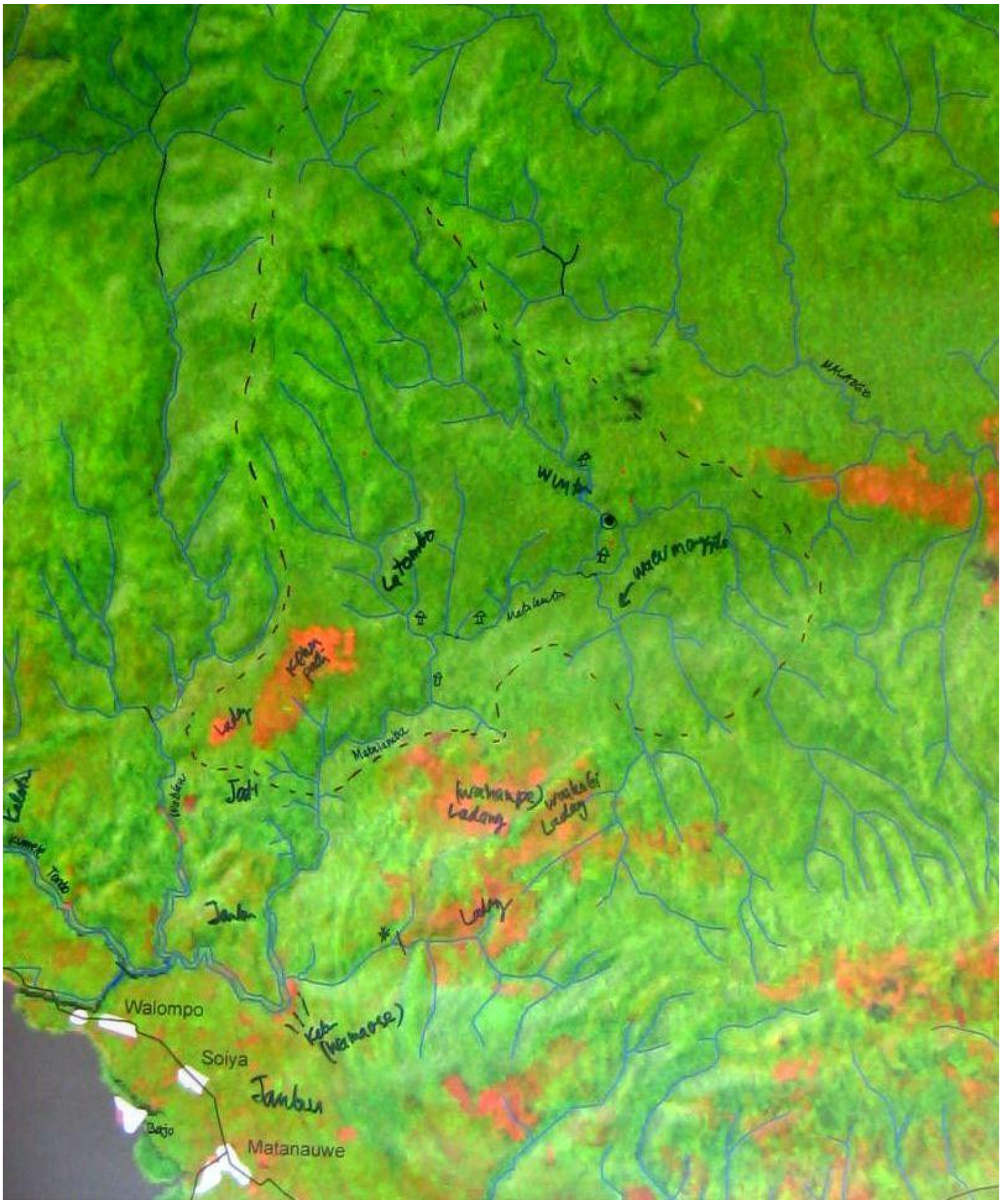


Figure A5.3. Adjustments on satellite imagery printout

Appendix 6. Facts and major livelihood characteristics of the villages in the study area

Village	Number Households*	Number Popula-tion*	Main livelihood activity	Rattan engagement	Other village facts
Lambusango Timur	128	-	Coastal-based, eg. mother-of pearl, seaweed	Two hamlets, both are engaged in rattan cane harvesting	
Wakangka	284	1061	Farming: tree-crop and irrigated rice	Four hamlets, three are engaged in rattan harvetsing	
Kakenauwe	70	319	Tree-crop farming: cashew and coconut; non-farm livelihood: farm labour and ecotourism labour	Two hamlets, both are engaged in rattan cane harvesting	
Lawele	400	-	Irrigated ricefields, cash crops	Six hamlets, four are engaged in rattan cane harvesting; one is coastal hamlet	
Sumbersari	354	1254	Tree-crop farming: cashew, cacao and ginger as newly developed crop	Three hamlets, all were engaged in rattan cane harvesting	Transmigration settlement, ethnicity is mostly Javanese
Walompo	204	951	Tree-crop farming cashew, teak.	Three hamlets were engaged in rattan cane harvesting	
Wining East	299	-	Tree-crop farming; mining labours, company labours	Two hamlet engaged in rattan cane harvesting	Wining East consists of two hamlets of Wining village
Wining West	92	-	Tree-crop farming; mining labours, company labours	One hamlet engaged in rattan cane harvesting	Wining West is one hamlet in Wining village

** information obtained from village authority and/or village contact and referring to the most updated available information, i.e. 2005-2006*

Appendix 7. Questionnaire for household and harvesting information

Section A. Household

1. Members in the household (HH)

1.1. Members in the HH [1)] and education

No.	Name	M/F	Age	Position in HH	Formal education	Occupation	Remarks

1) *HH members are all who live in the same house with the daily consumption from the particular HH, and include those who live away but depend on this particular HH.*

1.2 Are you originally from this area or are you a migrant?

....

1.3 If a migrant, when did you start leaving your home

....

1.4 What is/are the reason(s) for leaving your home

....

1.5 Income source(s) outside farming and forest extraction activities for the last 2-3 years

HH member	Permanent Job			Temporary Job		
	Type	When	Remarks on income	Type	When	Remarks on income

1.6. Notes for income from trading (*i.e. types of goods, seasonal or permanent, trading destinations),* home industry *(i.e. type of industry, raw materials and where obtained, family member involved, end product, seasonal or not, where to market),* room rental, etc

____

____

____

____

2. House condition

Land area	Building condition				Ownership					
					Own house		Rent/contract			Other
	area (m^2)	Building materials	Roof	Toilet? [1)]	Since when	Form of possession	Since when	How long	Price	

1) Yes or no

3. Farmland ownership and uses

3.1 Farmland Ownership

Land	Type of farmland[1)]	Area (m^2)	Way land obtained [2)]	If bought, how much? [3)]	Since when	Existing land use [4)]
I						
II						
III						
IV						
V						
VI						

1) E.g. homegardens, irrigated ricefield, rainfed ricefield, crop land
2) Purchased, inherited, given from government/somone
3) Price at purchase
4) Present land use, if rented to someone go to section 3.2

3.2 Land rented to others

Land	Type of farmland[1)]	Area (m^2)	Rent/ share method	Rent		Sharing		Type of land use
				For how long	price	For how long	Sharing system	

1) Refer to column 'land' table 3.1
2) E.g. homegardens, irrigated ricefield, rainfed ricefield, crop land

4. Activity other than rattan cane harvesting → Farming (if respondent doing farming)

4.1 What is your farming activity for each area of farmland for the past 1-2 years ?

Land (refer to table 3.1)	Activity	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Okt	Nov	Des

4.2 What inputs are needed for the farmlands ? (e.g. fertiliser, pesticide, seeds, etc)

Commodity	Input needed	Cost/unit	Number of unit	Time for each x unit(s)	Remarks

4.3 Do you also need labour for your farm activities? yes / no

Type of labour	Cost/ person	Nbr persons	Time/x person(s)	Remarks

4.4 From your farmland, how large is the harvest?

Commodity	Harvest amount (unit)	Amount being sold/marketed (unit)	Sale price (per unit)	Total sale	Market cost (per x unit)

5. Other cultivation/farming activities (fishery, livestock, poultry, etc)

5.1 Is there any other farming/cultivation activity as your source of income? …………………

5.2. If yes, what is the activity for each cultivation activity the past 1-2 years ?

Land/ ultivation unit	Activity	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Okt	Nov	Des

5.3 What are the inputs needed ?

Commodity	Input needed	Cost/unit	Number of unit	Time for each x unit(s)	Remarks

5.4 Do you also n eed labour ? yes/ no

Type of labour	Cost/ person	Nbr persons	Time/x person(s)	Remarks

5.5 How large is the harvest?

Commodity	Harvest amount (unit)	Amount being sold/marketed (unit)	Sale price (per unit)	Total sale	Market cost (per x unit)

6. Forest extraction activity (other than rattan harvesting)

6.1 Do you do any forest product extraction as an income source Yes / no

6.2 If yes, what is the commodity and how much is your income from that extraction activity (fill up the table)

Commodity	Total harvest amount (unit)	How much from harvest for sale (unit)	Time for activity	Price per unit	Total sale	Cost	Remarks

7. Family expenses

7.1 What are the expenses you have for education in your family?

Family member going through education		School/tuition fee			Books and stationary				Other expenses				remarks
Education level	Number of persons	Type of expense	How much	Time unit	Type of expense	How many (unit)	Price / unit	Time for each unit	Type of expense	How many (unit)	Price / unit	Time for each unit	
Elementary school													
Junior High													
Senior high													
College/University													

7.2 Can you estimate household expense for daily food and consumption ?

Item	Type	Number of unit	Price /unit	Time for x unit	Remarks
Food	Rice				
	Protein sources				
	Sugar				
	Coffee, tea				
	Spices				
	Kerosene				
	…………..				
Washing and bathing					
Clothing					
Electricity					
Water					
Communication					
Transportation					
………………………					

7.3 Can you estimate your other routine expenses ? (e.g. cigarettes, cosmetics for wife, gasoline, routine repairs, taxes, etc)

Expense	Nbr of unit	Cost/ unit	Time for x unit	Remarks

<u>Section B. Rattan Cane Harvesting</u>

1. Rattan collection general information

1. When did you start collecting rattan cane? Year:……………..
2. When was the last time you harvested rattan cane Year:
3. When you collect rattan, you go………….. alone/ in group
4. If in gorup, how many in one group ………. people

2. Harvesting area / coverage

5. Are the rattan areas determined by the buyer/middle man? Yes/ no
   Explanation………………………………………………………………………………………..
6. What are the names of rattan areas where you go and how do you carry the canes from there?

Place name	Trail/river	Place name	Trail/river

7. Where do you pile the canes before the weighing day?
8. Where do you weigh and sell the canes?
9. Distance and duration of rattan collection (village-forest)

	Distance from hamlet	Time to reach the place	Duration in harvesting canes	Break time	Time to return to the village
The farthest					
The closest					

3. Rattan names and prices

10. What are the rattan names that you collect ? (*fill up table*)
11. Perception/opinion: Why do you collect those rattans? ....
12. What rattans are bought by the buyer/middle man and how much ? (fill up table)

Type code	name	Answer (*tick*)	Bought (*tick)*	Price to the midlle man (past 2 yrs)		Notes on quality/class
				max	min	
R1	Batang asli					
R2	Batu					
R3	Bulurusa					
R4	Buta					
R5	Daramasi					
R7	Hoa					
R8	Kabe					
R9	Kai Sisau					
R10	Kakiki					
R11	Lakumpa					
R12	Lambang					
R13	Mombi					
R15	Ngasa					
R16	Noko					
R17	Pisi					
R18	Tohiti					
R19	Torumpu					
R20	Umbul					
	…………					

13. How are you paid for the canes you sell?

no	payment	Answer
a	Paid full in advance	
b	Given advance money	
c	Paid full directly after on the weighing day	
d	Paid in a few days after weighing day	
e	……………………………..	

4. Harvesting: Techniques

14. For harvestable cane, what is the minimum length in the plant/clump ………. m
15. What's the length at the tip of the cane(that is still with leaves) ……….m
16. What's the length of each cane that you harvest and sell ? ………. m
17. Do you include the lowest part of the stem to be harvested (*fill up table*)
18. What is the length of the left-over cane in the plant/clump (*fill up table*)

Rattan name	Lowest part included ? (*tick*)	Approximate length of the leftover	Notes

19. Did you harvest all the harvestable canes in the clump ? yes / no
    Explanation…………………………………………………………………………………………………

5. Harvesting : Quantity and time

20. How long in a year is a harvest season (=buyer operating in the village) ………..
21. How often is the weighing day …………
22. Do you collect rattan cane everytime there is a buyer coming to the village ? yes/no
23. How many months in a year do you collect rattan canes? …………
24. What months do you collect rattan cane?

Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec

25. During those months, do you collect rattan canes every week? Yes/no
26. If not then how many weeks in a month? *(choose one answer)*

no	How many weeks	Answer
a.	1 week	
b.	2 weeks	
c.	3 weeks	
d.	……………………..	

27. In a week what days do you usually go to collect rattan canes?

Mon	Tue	Wed	Thu	Fri	Sat	Sun

28. How many trips in a day do you go for collecting rattan canes ? ..… x
29. *(if collector also does farming).* What happens with your farming when you go to collect rattan?
    explanation………………………………………………………………………………………

30. How many canes do you carry in one collection trip and how much does the bundle weigh *(fill up table)*

Maximum		Minimum	
weight (max)	= canes (max)	Weight (min)	= canes (min)

31. Will you still be collecting rattan canes if there is a buyer coming to your village yes/no
    Why? ....
32. *(If no 31=yes)* What is the most important reason for you to still want to collect rattan canes?

No	Reason	Answer *(choose)*
a	High price ………………….	
b	Collection is during farming off-season anyway	
c	Collection when there are extra need in the household	
d	……………………………….	

6. Harvesting ecological impact

33. If you find rattan cane climbing high and difficult to pull, what do you do to take it?
    a. *Low level difficulty* – cane is stuck in one small tree
        i. If cane is difficult to pull, only cut the lowest part and the rest is left
        ii. If cane is difficult to pull, climb the tree, cut the cane and the rest is left
        iii. If cane is difficult to pull, cut the tree and harvest the cane
    b. *High level of difficulty* – if cane is climbing on two or more small trees
        i. If cane is difficult to pull, only cut the lowest part and the rest is left
        ii. If cane is difficult to pull, climb the tree, cut the cane and the rest is left
        iii. If cane is difficult to pull, cut the tree and harvest the cane

34. In search for the harvestable canes, if you find rattan clumps away from the main trail and access to that clump is obstructed by tree seedlings and shrubs, what do you do?
    a. *Low level difficulty* – if the clump is close by the main trail *(pick one answer)*
        i. Find an easy access to reach it even though far.
        ii. Find an easy access to reach it, if too far, take a shortcut
        iii. Make a shortcut
    b. *Medium level of difficulty* – if distance is medium and area with slopes *(pick one answer)*
        i. Find an easy access to reach it even though far.
        ii. Find an easy access to reach it, if too far, take a shortcut
        iii. Make a shortcut
    c. *High level of difficulty* – if it is far and rattan is located on steep area or hill top *(pick one answer)*
        i. Find an easy access to reach it even though far.
        ii. Find an easy access to reach it, if too far, take a shortcut
        iii. Make a shortcut

7. Local knowledge/wisdom

35. In your opinion, how can rattan plants reproduce to still exist in the forest?
    Explanation ………………………………………………………………………………
36. In your opinion, on the rattan canes in the forest, how is their abundance recently?
    Higher than previous years/ similar to pervious years/ lower than previous years
    Explanation…………………………………………………………………………..
37. Do you have a wish to grow rattan yourself in your own farm land ? yes/no
    Explanation…………………………………………………………………………..

38. Do you know the type of forest zone where you collect rattan canes yes/no
39. If yes, explain………………………………………………………………………………
40. Are there collectors coming from other villages to the area where you collect rattan canes? Yes/no
41. Do you think it's better that rattan harvesting area is specifically for collectors from certain village(s) or you think it's better as free access?
    Explanation…………………………………………………………………………

8. Input for harvesting

42. To go collecting rattan canes, what tools do you need ? *(fill up table)*
43. What is the price and where do you buy? *(fill up table)*
44. If bought outside the village, how much is the additional cost (e.g transport) *(fill up table)*
45. How long is that particular tool used for or for how many rattan collection trips/seasons ? *(fill up table)*

No	Tool(s)	Price	Where to buy	Cost	Duration of use (time unit)	Notes

Appendix 8. Forest and villages in the study area

Figure A8.1. Lambusango forest - evergreen lowland forest in central Buton (*top photo courtesy of Bruce Carlisle*)

Figure A8.2. Rattan canes arriving at the weighing place after being transported by bamboo raft along river

Figure A8.3. Rattan canes being sun dried at a rattan processing plant

Figure A8.4. (a) A truck with rattan cane load (b) basketry made by villagers utilising rattan canes

Figure A8.5. Forest loss due to a newly established settlement (*photo courtesy of Bruce Carlisle*)

Figure A8.6. Upland field (*kebun*) with huts for temporary dwelling

Figure A8.7. A village around Lambusango forest (*photo courtesy of Bruce Carlisle*)

Figure A8.8. Participatory mapping activity held at one village

List of abbreviations and acronyms

AGB	Above-ground Biomass
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
asl	above sea level
BPS	*Biro Pusat Statistik* (Central Bureau of Statistics)
BS	Base Saturation
CCA	Canonical Correspondence Analysis
CEC	Cation Exchange Capacity
CFMF	Community Forestry Management Forum
dbh	diameter at breast height
DC	Digital Counts
DN	Digital Numbers
EC	Electrical Conductivity
ETM	Enhanced Thematic Mapper
FGD	Focus Group Discussion
FWI	Forest Watch Indonesia
GEF	Global Environment Facility
GFW	Global Forest Watch
GIS	Geographic Information Systems
GLM	General Linear Model
GPS	Global Positioning Systems
HL	*Hutan Lindung* (Protection Forest)
HP	*Hutan Produksi* (Production Forest)
HPT	*Hutan Produksi Terbatas* (Limited Production Forest)
IDR	Indonesian Rupiah
IFOV	Instantaneous Field of View
IMF	International Monetary Fund
INBAR	International Network of Bamboo and Rattan
IUCN	International Union for Conservation of Nature
LFCP	Lambusango Forest Conservation Programme
LUC	Land use Change
MANCOVA	Multiple Analyses of Covariance
µm	Micrometer
NASA	National Aeronautics and Space Administration
NDVI	Normalised Difference Vegetation Index
NIR	Near Infra Red
NPV	Net Present Value
NTFP	Non Timber Forest Product
Opwall	Operation Wallacea
PAR	Photosynthetically Active Radiation
PCA	Principal Component Analysis
PES	Payments for Environmental Services
PGIS	Participatory GIS
PHKA	*Perlindungan Hutan dan Konservasi Alam* (Forest Protection and

	Nature Conservation)
PM	Participatory Mapping
PRA	Participatory Rural Appraisal
PRM	Participatory Resource Mapping
RDA	Redundancy Analysis
SD	*Sekolah Dasar* (Primary school)
SM	*Suaka Margasatwa* (Wildlife Reserve)
SMA	*Sekolah Menengah Atas* (High school)
SMP	*Sekolah Menengah Pertama* (Junior high school)
TM	Thematic Mapper
WI	Wealth Index
REDD	Reducing Emission from Deforestation and forest Degradation
UN-REDD	The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries

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